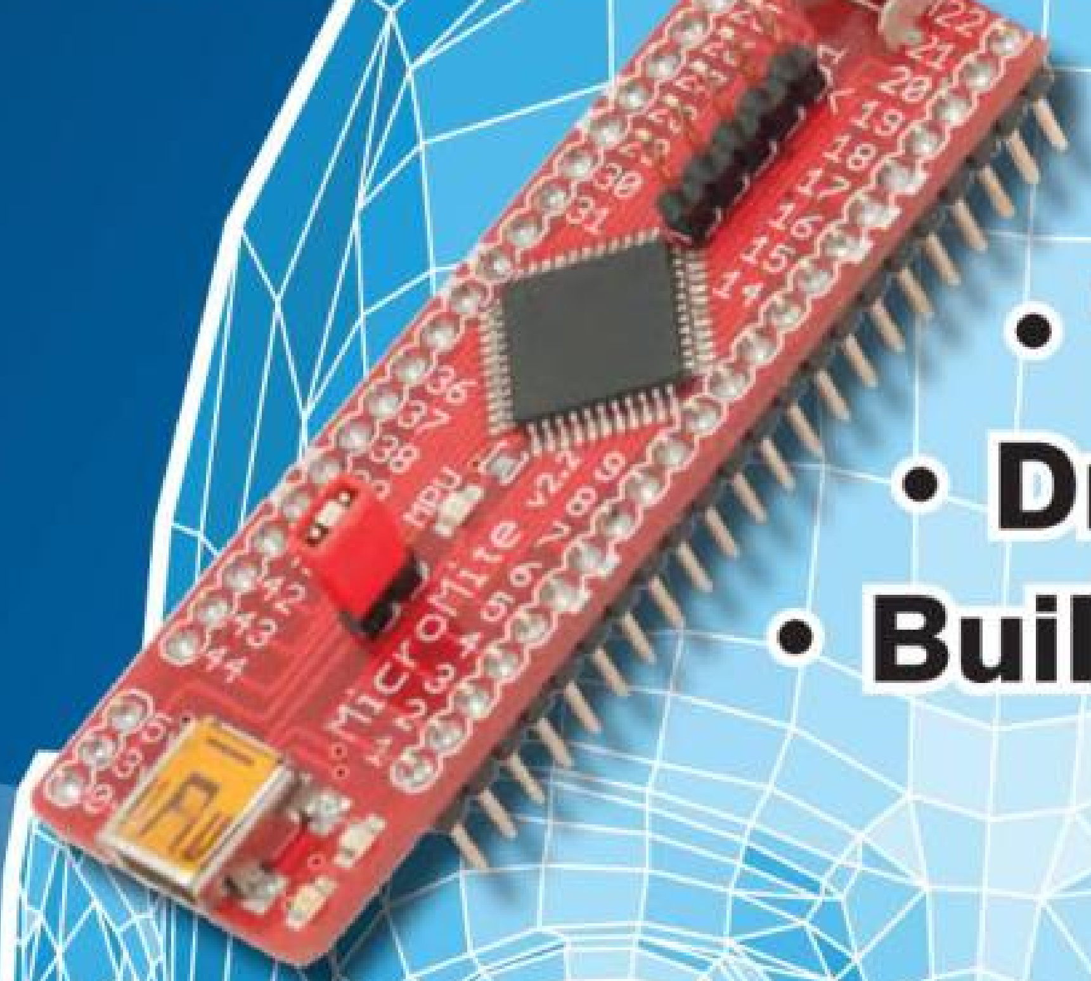
THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

WIN A MICROCHIP Curiosity PIC32MZ EF Development Board

THE MICROMITE LCD BACKPACK



- Colour TFT LCD
- Touch-sensitive screen
- Driven by Microchip 32-bit 48MHz microcontroller
- Built-in support for IR remote controls and sensors

ARDUINO MULTIFUNCTION 24-BIT MEASURING SHIELD – PART 2

Software, calibration and use

PRECISION 230V/115V, 50/60HZ TURNTABLE DRIVER

Run belt or idler-driven turntables at exactly the right speed

DON'T MISS OUT! LAST FEW LEFT!

Check out our AMAZING Microchip offer – see page 5

MICROCHIP
www.microchipDIRECT.com

MAY 2017 £4.40

AUDIO OUT, PIC n' MIX, COOL BEANS, TECHNO TALK, CIRCUIT SURGERY, READOUT & NET WORK

FUZE

FUZE Special Edition

- Protect your Pi from physical & static damage
- UK keyboard & Mouse
- FUZE I/O Board with 40 way GPIO pass-through
- Clearly labelled input output ports
- 3 Amp power supply and on/off switch!
- Adds analogue ports, 4 in & 1 out
- 840 pin solderless breadboard (black)
- 8GB SD pre-configured with FUZE BASIC

THE NATIONAL MUSEUM OF COMPUTING

"The FUZE is what the Raspberry Pi was designed for"

micro mart
EDITOR'S CHOICE
... it's certainly the **best** we've **ever** tested

PC PRO **Recommended**
...makes the Pi more accessible than ever

from
£99.99

FUZE Technologies Ltd
+44 (0) 1844 239 432 - contact@fuze.co.uk

Available from www.fuze.co.uk

QUICKDRONES

- 100% ready to fly. From box to air takes seconds
- Unified body design & incredibly durable
- 700TVL camera provides excellent FPV picture
- 2205 2300KV powerful motor
- Status LED to show battery & transmission channel
- One button to switch video channel & power
- DVR port for onboard recording
- Low battery & out of sight warning buzzer
- Available in various colours

The *VIFLY* R220 is a 100% ready-to-fly FPV Racing Drone, no assembly, no calibration, just fly it out of the box. The robust design protects the electrical components inside the frame and gives it an incredible ability to withstand violent crashes. The 3 digit LED display shows the battery voltage and a single button switches video transmission channel and power output. The addition of a DVR port and warning buzzer, makes flying the VIFLY R220 FPV drone easier than ever.

price
£349.99
Including VAT
and UK delivery

BinaryDistribution Ltd
+44 (0) 1844 239 432 - admin@binarydistribution.co.uk

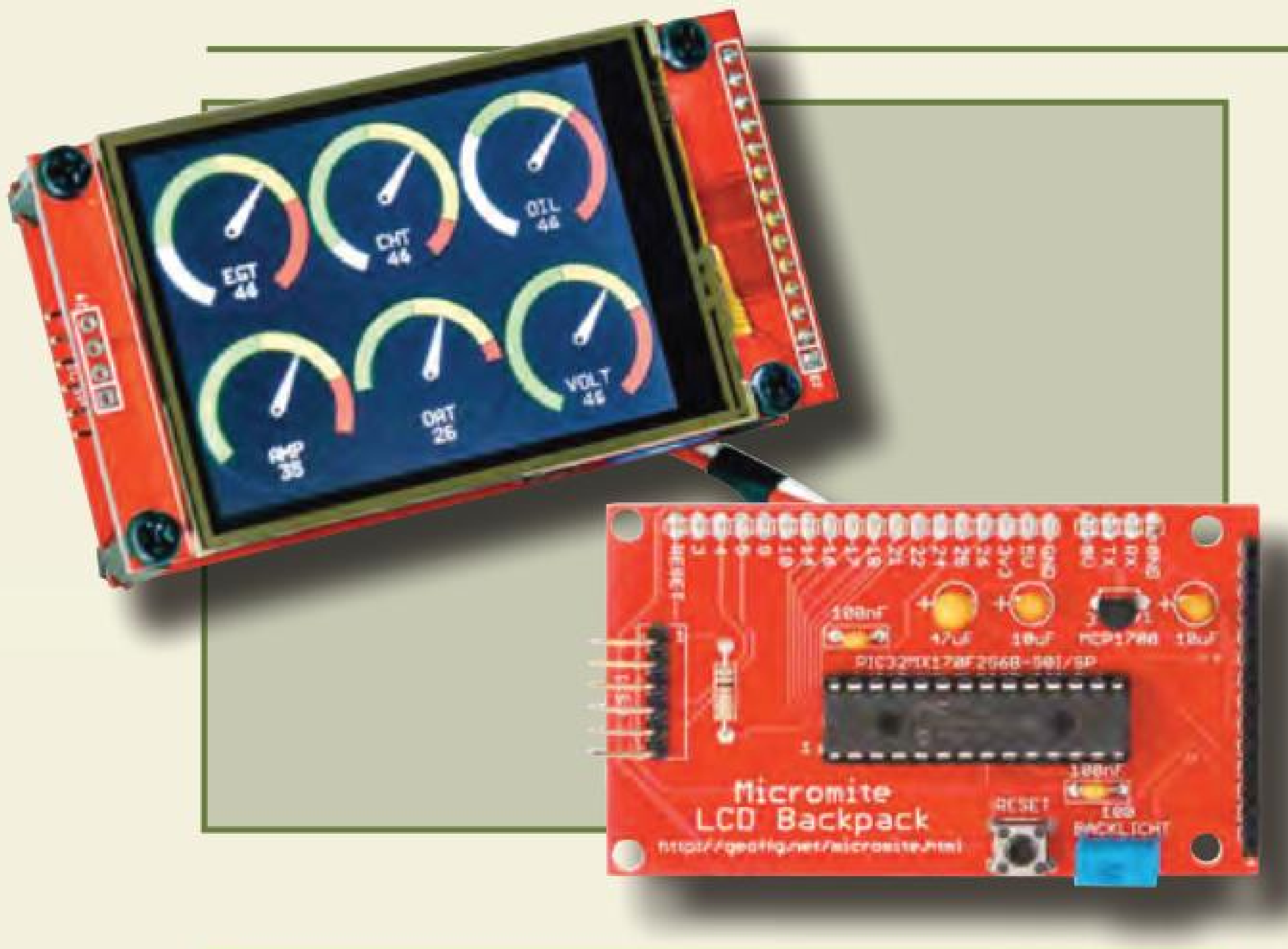
www.quickdrones.co.uk

ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
VOL. 46. No 5 May 2017

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

www.epemag.com



EPE product review
Smith & Larson
Audio
Woofer Tester 2

Projects and Circuits

THE MICROMITE LCD BACKPACK 12
by Geoff Graham
For your next project, add this superb full-colour touch-sensitive LCD panel with a low-cost 32-bit microcontroller running a BASIC interpreter

ARDUINO MULTIFUNCTION 24-BIT MEASURING SHIELD – PART 2 24
by Jim Rowe
Software installation, calibration and how to use the finished unit

PRECISION 230V/115V 50/60HZ TURNTABLE DRIVER 30
by John Clarke
Precise speed control of belt-driven or idler-driven turntables using 230VAC at 50Hz or 115VAC at 60Hz

Series and Features

TECHNO TALK by Mark Nelson 11
Questionable gratification, strange science

NET WORK by Alan Winstanley 40
Wireless printing... Not so Eudorable?... Credit where it's due
Amazon gets more Stick

***EPE* PRODUCT REVIEW** by Julian Edgar 42
Smith & Larson Audio – Woofer Tester 2

INTERFACE by Robert Penfold 44
micro:bit ins and outs

PIC n' MIX by Mike O'Keeffe 48
PICs and the PICkit 3: A beginner's guide – Part 10

CIRCUIT SURGERY by Ian Bell 52
Logic timing and timing diagrams

AUDIO OUT by Jake Rothman 57
MX50 power amplifier kit – Part 1

MAX'S COOL BEANS by Max The Magnificent 68
The secret of my success… The tragedy of the iPad... The triumph of the iPad

Regulars and Services

SUBSCRIBE TO *EPE* and save money 4

***EPE*–MICROCHIP SPECIAL OFFER – NOT TO BE MISSED!** 5

EDITORIAL 7
Energy density

NEWS – Barry Fox highlights technology's leading edge 8
Plus everyday news from the world of electronics

MICROCHIP READER OFFER 22
EPE Exclusive – Win a Microchip Curiosity PIC32MZ EF Development Board

***EPE* BACK ISSUES CD-ROM** 39

FARNELL ELEMENT 14 OFFER 55
EPE Exclusive – Win the latest BeagleBone® Blue Development board

***EPE* BACK ISSUES** 56

READOUT – Matt Pulzer addresses general points arising 60

***EPE* CD ROMS FOR ELECTRONICS** 62
A wide range of technical books available by mail order, plus more CD-ROMs

NEW ADDITION TO OUR *TEACH-IN* SERIES – *EPE* TEACH-IN 8 65

DIRECT BOOK SERVICE 66
A wide range of technical books available by mail order, plus more CD-ROMs

***EPE* PCB SERVICE** 70
PCBs for *EPE* projects

ADVERTISERS INDEX 71

NEXT MONTH! – Highlights of next month's *EPE* 72

© Wimborne Publishing Ltd 2017. Copyright in all drawings, photographs and articles published in *EVERYDAY PRACTICAL ELECTRONICS* is fully protected, and reproduction or imitations in whole or in part are expressly forbidden.

Our June 2017 issue will be published on Thursday 4 May 2017, see page 72 for details.

Readers' Services • Editorial and Advertisement Departments *7*

Quasar Electronics Limited
PO Box 6935, Bishops Stortford
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.co.uk
Web: www.quasarelectronics.co.uk

All prices INCLUDE 20.0% VAT. Free UK delivery on orders over £35
Postage & Packing Options (Up to 0.5Kg gross weight): **UK Standard 3-7 Day Delivery** - £3.95; **UK Mainland Next Day Delivery** - £8.95; **Europe (EU)** - £12.95; **Rest of World** - £14.95 (up to 0.5Kg).
Order online for reduced price Postage (from just £3)
Payment: **We accept all major credit/debit cards. Make PO's payable to Quasar Electronics Limited.**
Please visit our online shop now for full details of over 1000 electronic kits, projects, modules and publications. Discounts for bulk quantities.

01279 Card Sales & Enquiries **467799**

Solutions for Home, Education & Industry Since 1993

PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £9.95
18Vdc Power supply (661.130UK) £23.95
Leads: Parallel (LDC136) £2.56 | Serial (LDC441) £2.75 | USB (LDC644) £2.14

PIC Programmer & Experimenter Board

Great learning tool. Includes programming examples and a reprogrammable 16F627 Flash Microcontroller. Test buttons & LED indicators. Software to compile & program your source code is included. Supply: 12-15Vdc. Pre-assembled and ready to use.
*Order Code: VM111 - **~~£38.88~~ £30.54***

USB PIC Programmer and Tutor Board

The only tutorial project board you need to take your first steps into Microchip PIC programming using a PIC16F882 (included). Later you can use it for more advanced programming. Programs all the devices a Microchip PICKIT2® can! Use the free Microchip tools for PICKit2™ & MPLAB® IDE environment.
*Order Code: EDU10 - **£46.74***

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. 16Vdc.
*Kit Order Code: 3123KT - **~~£32.95~~ £21.95***
*Assembled ZIF: AS3123ZIF- **~~£48.96~~ £37.96***

USB /Serial Port PIC Programmer

Fast programming. Wide range of PICs supported (see website for details). Free Windows software & ICSP header cable. USB or Serial connection. ZIF Socket, leads, PSU not included.
*Kit Order Code: 3149EKT - **~~£49.96~~ £29.95***
*Assembled Order Code: AS3149E - **£44.95***
*Assembled with ZIF socket Order Code: AS3149EZIF - **~~£74.96~~ £49.95***

PICKit™2 USB PIC Programmer Module

Versatile, low cost, PICKit™2 Development Programmer. Programs all the devices a Microchip PICKIT2 programmer can. Onboard sockets & ICSP header. USB powered.
*Assembled Order Code: VM203 - **£39.54***

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £10.68

USB Experiment Interface Board

Updated Version! 5 digital inputs, 8 digital outputs plus two analogue inputs and two analogue outputs. 8 bit resolution. DLL.
*Kit Order Code: K8055N - **~~£39.95~~ £22.74***
*Assembled Order Code: VM110N - **£39.95***

2-Channel High Current UHF RC Set

State-of-the-art high security. Momentary or latching relay outputs rated to switch up to 240Vac @ 12 Amps. Range up to 40m. 15 Tx's can be learnt by one Rx. Kit includes one Tx (more available separately). 9-15Vdc.
*Kit Order Code: 8157KT - **£44.95***
*Assembled Order Code: AS8157 - **£49.96***

Computer Temperature Data Logger

Serial port 4-ch temperature logger. °C/°F. Continuously log up to 4 sensors located 200m+ from board. Choice of free software applications downloads for storing/using data. PCB just 45x45mm. Powered by PC. Includes 1xDS1820 sensor.
*Kit Order Code: 3145KT - **~~£19.95~~ £16.97***
*Assembled Order Code: AS3145 - **£22.97***
*Additional DS1820 Sensors - **£4.96 each***

8-Channel Ethernet Relay Card Module

Connect to your router with standard network cable. Operate the 8 relays or check the status of input from anywhere in world. Use almost any internet browser, even mobile devices. Email status reports, programmable timers... Test software & DLL online.
*Assembled Order Code: VM201 - **£134.40***

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
*Kit Order Code: 3179KT - **£17.95***
*Assembled Order Code: AS3179 - **£24.95***

Many items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix)

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/5A) in both the forward and reverse directions. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. PCB: 90x42mm.
*Kit Order Code: 3166KT - **£19.95***
*Assembled Order Code: AS3166 - **£25.95***

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our free Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
*Kit Order Code: 3108KT - **£74.95***
*Assembled Order Code: AS3108 - **£89.95***

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ indoor range. 112 x 122mm. Supply: 12Vdc/500mA
*Kit Order Code: 3142KT - **~~£64.96~~ £59.96***
*Assembled Order Code: AS3142 - **£69.96***

Temperature Monitor & Relay Controller

Computer serial port temperature monitor & relay controller. Accepts up to four Dallas DS18S20 / DS18B20 digital thermometer sensors (1 included). Four relay outputs are independent of the sensors giving flexibility to setup the linkage any way you choose. Commands for reading temperature / controlling relays are simple text strings sent using a simple terminal or coms program (e.g. HyperTerminal) or our free Windows application. Supply: 12Vdc.
*Kit Order Code: 3190KT - **~~£79.96~~ £49.96***
*Assembled Order Code: AS3190 - **£59.95***

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone or 2-wire serial interface for microcontroller or PC communication with simple command set. Suits common anode RGB LED strips, LEDs, incandescent bulbs. 12A total max. Supply: 12Vdc. 69x56x18mm
*Kit Order Code: 8191KT - **£29.95***
*Assembled Order Code: AS8191 - **£29.95***

QUASAR electronics

velleman

cebek

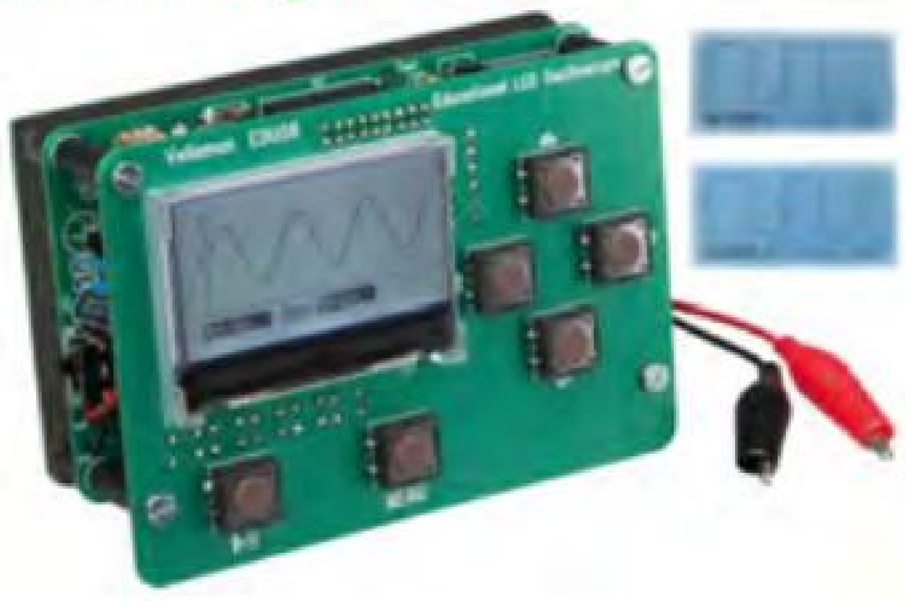
Official UK Main Dealer

Stocking the full range of Cebek & Velleman Kits, Mini Kits, Modules, Instruments, Robots and more...

Card Sales & Enquiries 01279 467799

2-Ch WLAN Digital Storage Scope
Compact, portable battery powered fully featured two channel oscilloscope. Instead of a built-in screen it uses your tablet (iOS, Android™ or PC (Windows) to display the measurements. Data exchange between the tablet and the oscilloscope is via WLAN. USB lead included.
*Code: WFS210 - **£161.95** iinc VAT & Free UK Delivery*

LCD Oscilloscope Self-Assembly Kit
Build your own oscilloscope kit with LCD display. Learn how to read signals with this exciting new kit. See the electronic signals you learn about displayed on your own LCD oscilloscope. Despite the low cost, this oscilloscope has many features found on expensive units, like signal markers, frequency, dB, true RMS readouts. 64 x 128 pixel LCD display.
*Code: EDU08 - **£49.99** inc VAT & Free UK Delivery*



200 Watt Hi-Fi Amplifier, Mono or Stereo (2N3055)
Self-assembly kit based on a tried, tested and reliable design using 2N3055 transistors. Relay soft start delay circuitry. Current limiting loudspeaker protection. Easy bias adjustment. Circuit consists of two separate class AB amplifiers for a STEREO output of up to 100 Watts RMS @ 4Ω / channel or a MONO output of up to 200W @ 4Ω. Includes all board mounted components and large pre-drilled heatsink.
*Order Code 1199KT - **£69.95** inc VAT & Free UK delivery*

2MHz USB Digital Function Generator for PC
Connect with a PC via USB. Standard signal waves like sine, triangle and rectangle available; other sine waves easily created. Signal waves are created in the PC and produced by the function generator via DDS (Direct Digital wave Synthesis). 2 equal outputs + TTL Sync output. Output voltage: 1mVtt to 10Vtt @ 600 Ohms.
*Code: PCGU1000 - **£161.95** inc VAT & Free UK delivery*

2MHz USB PC FUNCTION GENERATOR

PC-Scope 1 Channel 32MS/s With Adapter
0Hz to 12MHz digital storage oscilloscope, using a computer and its monitor to display waveforms. All standard oscilloscope functions are available in the free Windows program supplied. Its operation is just like a normal oscilloscope. Connection is through the computer's parallel port, the scope is completely optically isolated from the computer port. Supplied with one insulated probe x1/x10.
*Code: PCS100A - **£124.91** inc VAT & Free UK Delivery*

Oscilloscope
Spectrum Analyser
Transient Recorder

2-Channel PC USB Digital Storage Oscilloscope
Uses the power of your PC to visualize electrical signals. High sensitivity display resolution (down to 0.15mV), high bandwidth and sampling frequency up to 1GHz. Easy setup USB connection. No external power required! In the field measurements using a laptop have never been this easy. Stylish vertical space saving design. Powerful free Windows software.
*Code: PCSU1000 - **£246.00** inc VAT & Free UK Delivery*

Measurement up to 2 x 60MHz!
USB
Pc-Lab2000SE
TWO 60MHz PROBES
OSCILLOSCOPE
TRANSIENT RECORDER
SPECTRUM ANALYSER

Four Legged AllBot Kit
From the AllBot modular robot system with Arduino® compatible robot shields. Build and enhance the robot, learn how to program, use the app and have fun! Includes all necessary plastic parts, 4 x 9G servo motors, a servo motor connector shield (VRSSM), a battery shield (VRBS1).
*Code: VR408 - **£104.34** inc VAT & Free UK delivery*

PC USB Oscilloscope & Function Generator
Complete USB-powered Lab-in-a-Box! Free feature-packed software for two channel oscilloscope, spectrum analyser, recorder, function generator and bode plotter. With the generator, you can create your own waveforms using the integrated signal wave editor. For automated measurements, it is even possible to generate wave sequences, using file or computer RS232 input. 60MHz scope probe included
*Code: PCSGU250 - **£135.60** inc VAT & Free UK Delivery*

No.1 FOR KITS

www.QuasarElectronics.co.uk

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Images • Kit Documentation & Software Downloads

E&OE

PRICE FROZEN

EPE EVERYDAY PRACTICAL ELECTRONICS

SUBSCRIPTION PRICES FROZEN FOR 2017

UK readers you can SAVE 81p on every issue of *EPE*

How would you like to pay £3.59 instead of £4.40 for your copy of *EPE*?

Well you can – just take out a one year subscription and save 81p an issue, or £9.80 over the year. You can even save £1.08 an issue if you subscribe for two years – a total saving of £26.10

Overseas rates also represent exceptional value

You also:

- **Avoid any cover price increase for the duration of your subscription**
- **Get your magazine delivered to your door each month**
- **Ensure your copy, even if the newsagents sell out**

Order by phone, or fax with a credit card, or by post with a cheque or postal order, or buy online from www.epemag.com (go to the Online Shop).

EPE EVERYDAY PRACTICAL ELECTRONICS

SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in the UK: 6 months £23.50, 12 months £43.00, two years £79.50; Europe Airmail: 6 months £28.00, 12 months £52.00, 24 months £99.00; Rest Of The World Airmail: 6 months £37.00, 12 months £70.00, 24 months £135.00.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Tel: 01202 880299. Fax: 01202 843233. **Email:** subs@wimborne.co.uk. Also via the **Web** at**:** **www.epemag.com**.

Subscriptions start with the next available issue. We accept MasterCard, Maestro or Visa. (For past issues see the Back Issues page.)

ONLINE SUBSCRIPTIONS

Online subscriptions, for reading the magazine via the Internet, £19.99 for one year, visit **www.epemag.com** for more details.

SUBSCRIPTION ORDER FORM

☐ 6 Months: UK £23.50, Europe £28.00 (Airmail), Rest Of The World £37.00 (Airmail)
☐ 1 Year: UK £43.00, Europe £52.00 (Airmail), Rest Of The World £70.00 (Airmail)
☐ 2 Years: UK £79.50, Europe £99.00 (Airmail), Rest Of The World £135.00 (Airmail)

To: Everyday Practical Electronics,
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU
Tel: 01202 880299 Fax: 01202 843233
E-mail: subs@epemag.wimborne.co.uk

I enclose payment of £ .... (cheque/PO in £ sterling only), payable to *Everyday Practical Electronics*

☐ Please charge my Visa/Mastercard/Maestro

My card number is: ....
Please print clearly, and check that you have the number correct

Signature ....

Card Security Code .... Valid From Date.......................
(The last 3 digits on or just under the signature strip)

Card Ex. Date ....

Name ....

Address ....

Post code .... Tel. ....

Subscriptions can only start with the next available issue.

MasterCard VISA

EXCLUSIVE OFFER

Microchip and EPE have teamed up to bring you this AMAZING offer

MPLAB® IDE
Includes: MPLAB IDE, Documentation, Quick Reference Cards, Language Tool Demos, User Guides and Tutorials
MICROCHIP
PICkit 3
POWER
ACTIVE
STATUS

USUAL PRICE
£68.64
(Inc VAT)
(model DV164131)

The PICkit 3 allows debugging and programming of PIC and dsPIC Flash microcontrollers using the powerful graphical user interface of the MPLAB Integrated Development Environment (IDE). This kit includes the 44-pin demo board with a PIC18F45K20 microcontroller and a USB cable. Microchip's FREE MPLAB IDE software and the FREE Edition of the C Compiler provide a complete code development environment, and are available via free download from microchip.com

Spend over £125 on any of EPE's products, including subscriptions, and receive a PICkit 3 worth £68.64 for FREE

This offer is available to UK & overseas customers; however, for orders in Europe & ROW the following amounts will be added to cover postage:
£4.05 Europe: £5.10 ROW

Only 30 left, so hurry while stocks last!

Go to www.epemag.com to check availability

(Please note: subscriptions purchased with this offer cannot be cancelled before they expire; also, goods purchased with this offer can only be returned for exchange)

OFFER ONLY VALID WHILE STOCKS LAST – DON'T MISS OUT!!
JUST CALL 01202 880299 OR VISIT OUR SECURE ONLINE SHOP AT: www.epemag.com

MICROCHIP
www.microchipDIRECT.com

EPE EVERYDAY PRACTICAL ELECTRONICS

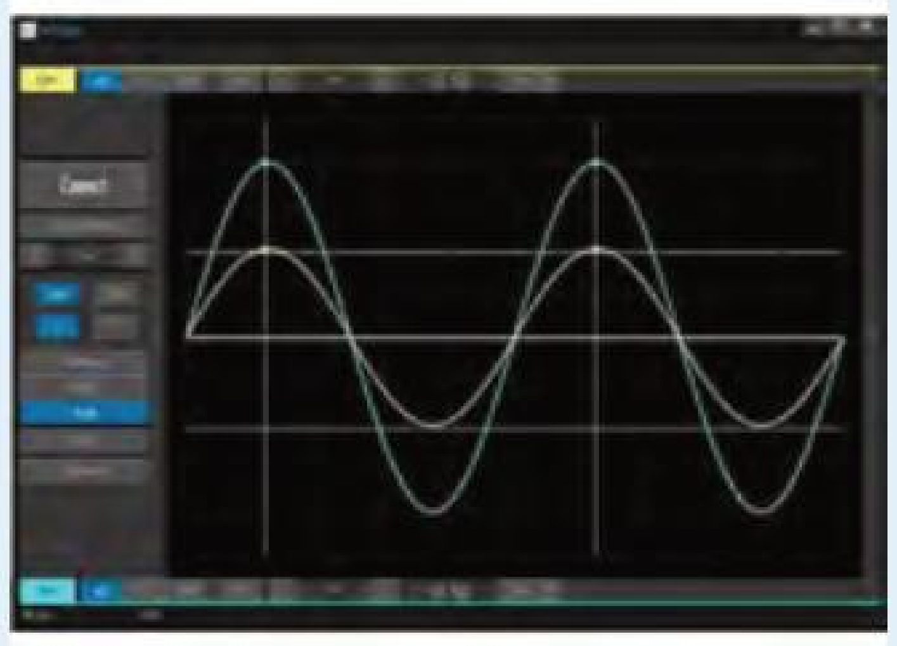
Sales: 0191 251 4363 www.TheElectronicsShop.co.uk

WFS210 2 Channel WLAN Scope

The Velleman WFS210 is the world's first WLAN dual channel digital storage oscilloscope geared towards tablet computers. A compact, portable battery powered fully featured. Instead of a built-in screen it uses your tablet (iOS, Android™ or PC(Windows)) to display the measurements. Data exchange between the tablet and the oscilloscope is via WLAN.

- High sensitivity: up to 0.2mV
- Full auto setup function
- Signal markers / Hold function
- DVM readouts
- Li-ion rechargeable battery included (3.7V 1800mAh)
- Input range: 5mV to 20V/div (12 steps)
- Timebase: 1μs to 1s/div
- Max. 30Vpp input
- Bandwidth: 2 x 10MHz (-3dB at selected ranges)
- Readouts: DC, AC+DC, True RMS, dBm, Vpp, Vmin, Vmax. Quote: EPEWFS

£79.20
Inc Delivery* & VAT



Offical Arduino Dealer
Genuine Arduino UNO R3
from £18.98+p&p
ARDUINO
Wide range of Boards,Shields & Accessories

HPS140MK2 Oscilloscope

£119.94
Inc Delivery* & VAT

The HPS140MK2 handheld oscilloscope still holds the same power as its predecessor, but in a new and modern design. Although small in size, this oscilloscope packs 40 MS/s in real time and it's sensitivity can go as low as 0.1 mV. It also has a full automatic measuring system but can be operated manually if preferred.

velleman

- 40 Mega samples/sec in real time
- Bandwidth up to 10 MHz
- Full auto range option
- Signal markers for amplitude and time
- Memory hold function
- Direct audio power measurement
- Stylish OLED Display Quote: EPEHPS2

HPG1 Function Generator

velleman

A complete pocket function generator. Now you can take test signals on the move, 3 waveforms can be selected. Set the output voltage or frequency and select signal waveform using the on the screen menu. A powerful sweep function is also included.

* Frequency range: 1Hz to 1.000.000Hz
* Frequency steps: 1Hz, 10Hz, 100Hz, 1kHz and 10kHz
* Sine, square and triangle wave forms
* Runs on NiMH rechargeable battery pack (includeed)
* BNC Lead and Charger Included.
Quote: EPEHPG

£91.19
Inc Delivery* & VAT

2.4GHz Frequency Counter

0.01Hz to 2.4GHz
8 Digit LED Display
Gate Time: 100ms to 10s
2 Channel Operating mode
Power Supply: 110-220Vac 5W
Quote: EPE24G

velleman

£81.00
Inc Delivery* & VAT

30V 5A Programmable PSU

Dual LED (Voltage & Current) Displays
Course & Fine Voltage /Current Adjustment
Volatge or Current Limiting.
* 5 Memories
* PC Link via USB
or RS232
*Output:
0-30Vdc
0-5A

Quote: EPEPSU

£99.90
Inc Delivery* & VAT

Build your own Oscilloscope

A new self assembly kit, ideal for education and way to visualise signals. Features: Markers, Frequency, dB, True RMS readouts
Timebase range:
10μs-500ms/division (15 steps)
Input sensitvity:
100mV-5V/division (6 steps)
Max Input voltage: 30Vpp
Max Sample Rate:
1ms/s repetitive signal,
100ks/s real time signal
Dim: 80 x 115 x 40mm

Quote: EPESCOPE

£49.99
Inc Delivery* & VAT

ESR ELECTRONIC COMPONENTS
www.esr.co.uk

05/17

Tel: 0191 2514363
Fax: 0191 2522296
sales@esr.co.uk

ESR Electronic Components Ltd
Station Road,
Cullercoats, Tyne &
Wear. NE30 4PQ

Prices **INCLUDE** Delivery* & VAT.
*Delivery to any UK Mainland address, please call for delivery options for Highland & Island, Northern Ireland, Ireland, Isle of Man, Isle of Wight & Channel Islands

VOL. 46 No. 05 MAY 2017

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS
EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299. **Fax:** 01202 843233.
Email: fay.kearn@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor:	MATT PULZER
Subscriptions:	MARILYN GOLDBERG
General Manager:	FAY KEARN
Graphic Design:	RYAN HAWKINS
Editorial/Admin:	01202 880299
Advertising and Business Manager:	STEWART KEARN 01202 880299
On-line Editor:	ALAN WINSTANLEY
Publisher:	MIKE KENWARD

READERS' TECHNICAL ENQUIRIES
Email: fay.kearn@wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

EPE EVERYDAY PRACTICAL ELECTRONICS

Energy density

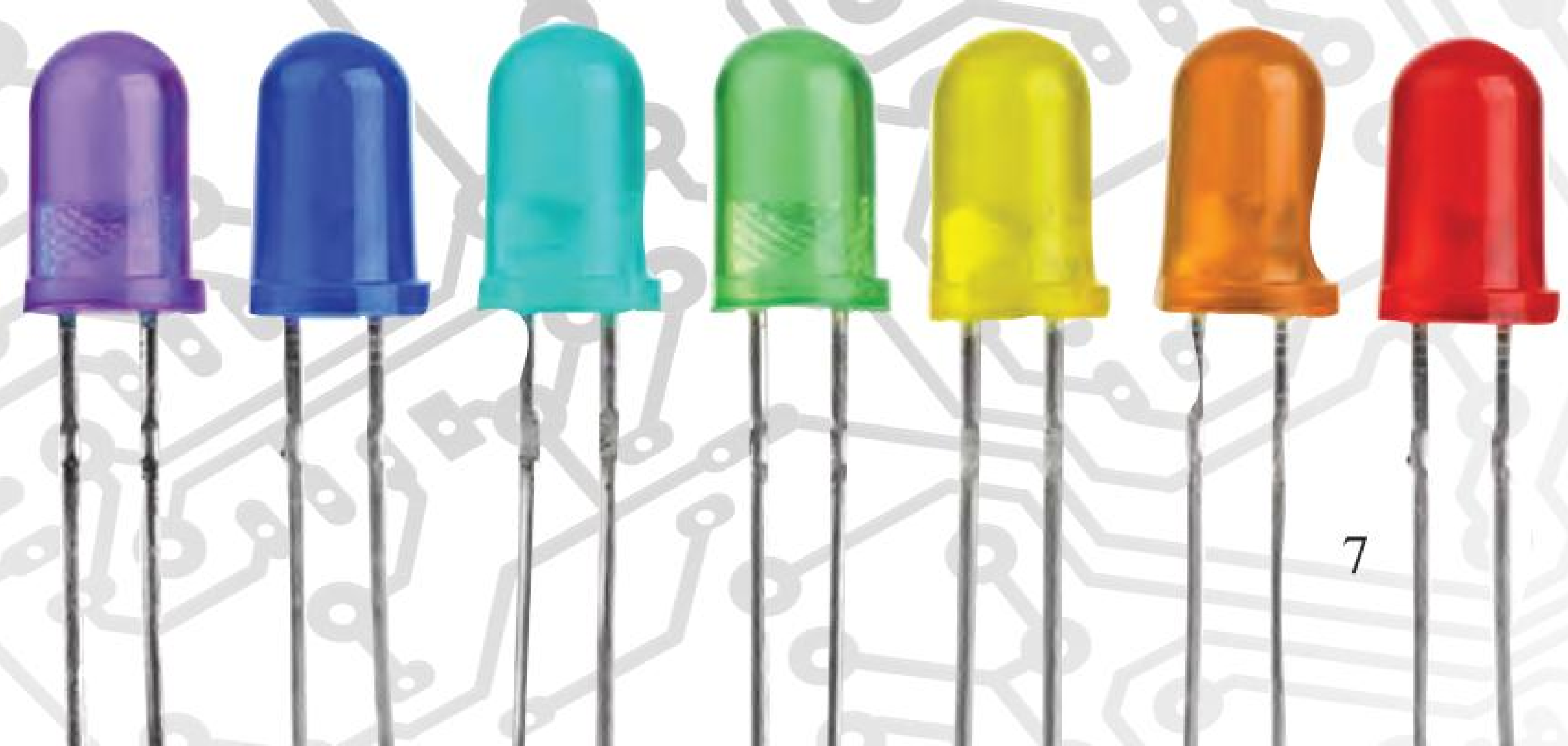
This month's *News* article on a potential upgrade to the now-ubiquitous lithium-ion battery really caught my attention. The design comes from one of the original inventors of the lithium-ion battery and that pedigree gives the story a lot of credibility. This is not some minor tweaking of an existing technology – the claimed three-fold increase in energy density could be just the quantum leap in storage capacity that the electric car industry needs to really take off. It will be fascinating to see how this new battery formulation progresses.

Energy density is an interesting concept and digging around on the Internet I came across some revealing statistics. The rechargeable lead-acid battery dates back to 1859, invented by French physicist Gaston Planté. They are heavy and therefore have a relatively poor energy density of around 0.17MJ/kg (megajoules per kilogram). However, they are cheap, rugged and can supply very large surge currents for automotive starter motors and hence have survived for 150 years in an industry notable for rapidly discarding elderly technologies.

Alkaline batteries, which date from the 1950s pushed energy density to 0.5MJ/kg. Rechargeable lithium-ion batteries range from around 0.36-0.875MJ/kg. So a new battery with perhaps an energy density of 2.5MJ/kg represents a fifteen-fold improvement over lead-acid, which is quite an achievement. But how does it compare to other energy sources? The numbers involved really do highlight the attraction and longevity of chemical energy. Even humble wood has a typical energy density of 16MJ/kg and petrol offers a huge 46MJ/kg. Plus, a petrol tank is easy and quick to 'recharge'. I won't go into the pros and cons of petrol – you undoubtedly know them already, but these figures do help explain why it is a tough energy source to displace.

Is petrol as good as it gets? No, two other sources beat it. Hydrogen comes out top of the chemical pile, with 142MJ/kg, but its very low volumetric density means that even when compressed to 700 bar it is still a space-hungry source of energy, and in terms of megajoules per litre (MJ/L) it is little better than the best batteries.

So, what's the winner; fancy a fuel with 80,000,000MJ/kg in your car? First, the good news, it's not a fairy tale, it really exists. The bad news is the wonder fuel is uranium, as used in a breeder reactor. If a typical road car achieves around 40mpg and has a road life of 100,000 miles then you could expect to use about 2,500 gallons of petrol over the lifetime of the vehicle. That's around 11,500 litres, which coincidentally is not far off the volume of a car like Ford Focus. If you could replace all that petrol with uranium you'd need around 250mm^3 of the stuff – about the size of a pea. Sadly, driving safely with a nuclear reactor under the bonnet is a contradiction in terms, so for now we'll have to stick with hydrocarbons and batteries.



NEWS

A roundup of the latest Everyday News
from the world of
electronics

Russians takes the fight to ransomware – report *by Barry Fox*

Russia is often blamed for computer hacks, so it is good to see Russians fighting hacking.

With warm words of support from Russian computer security software specialist Kaspersky Lab, backup software company Acronis – headed up by Russians CEO Serguei Beloussov and ex-Kaspersky Vice President Engineering Nikolai Grebennikov – is taking on the newest IT threat, ransomware.

Demonstration

At a London briefing recently, Beloussov and Grebennikov gave a live practical demonstration of what ransomware can do and how it works. They deliberately infected a Windows 10 PC with new ransom malware called DeviaLock, which then silently encrypted the computer's data files and displayed a screen message that threatened to permanently ruin the PC by destroying the hard disc's Master Book Record unless the owner paid cash to a Skype account in return for de-encryption keys. An on-screen clock gave a countdown of hours left to pay before irrevocable damage was done.

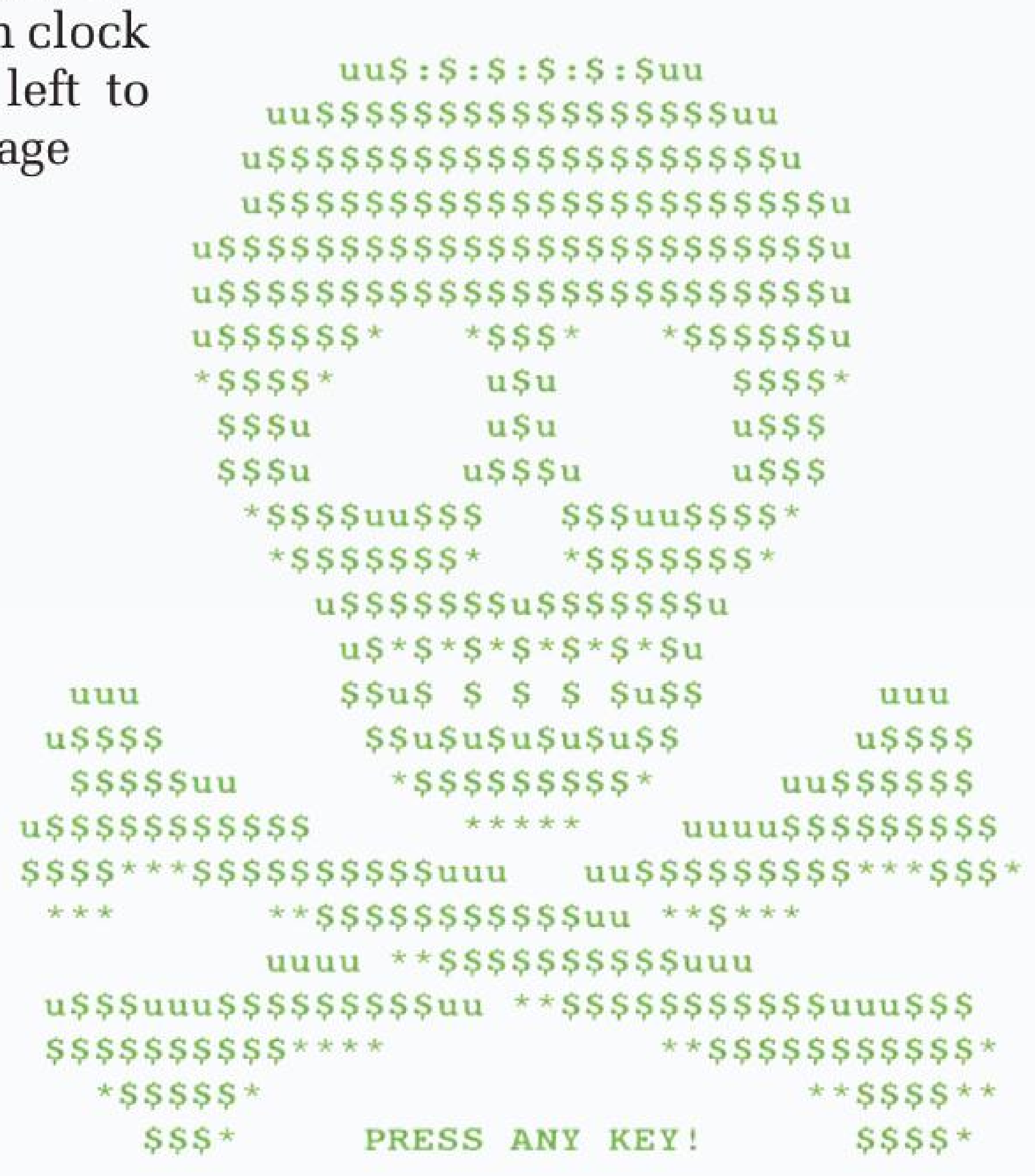
The object of the scary demonstration was to show how new backup software, Acronis True Image 2017 New Generation, counters such threats by continually backing up files either to a local hard drive or cloud store, or both, with the stored files locked against alteration. When the software detects that files on a PC are being altered by malware encryption it replaces them with clean backups from the store.

Eugene Kaspersky, chairman and CEO of Kaspersky Lab says: 'A high-end Internet security suite and a reliable backup disconnected from the system is still essential to ensure business continuity if the worst does happen. And I welcome Acronis's introduction of backup suited to this trend'.

Little choice but to pay up

Simon Edwards of SE Labs, the British company which tests IT services and software for security loopholes, warns: 'Unless you have access to government-grade quantum computing tools there is no way to find ransomware encryption keys without paying the ransom'.

'Most PCs get infected by people clicking on a link buried in a trap email,' Simon Edwards explained. 'Often the email will be disguised to look as if it has come from someone you know, on a familiar topic. This is because the hacker has already got access to their email account'.



```
              uu$:$:$:$:$:$uu
          uu$$$$$$$$$$$$$$$$$$uu
         u$$$$$$$$$$$$$$$$$$$$$$u
         u$$$$$$$$$$$$$$$$$$$$$$$$$u
       u$$$$$$$$$$$$$$$$$$$$$$$$$$$u
       u$$$$$$$$$$$$$$$$$$$$$$$$$$$u
       u$$$$$$*    *$$$*    *$$$$$$u
       *$$$$*       u$u        $$$$*
        $$$u        u$u        u$$$
        $$$u       u$$$u       u$$$
         *$$$$uu$$$    $$$uu$$$$*
          *$$$$$$$$*   *$$$$$$$$*
            u$$$$$$$u$$$$$$$u
              u$*$*$*$*$*$*$u
  uuu         $$u$ $ $ $ $u$$        uuu
 u$$$$         $$u$u$u$u$u$$        u$$$$
  $$$$$uu       *$$$$$$$$$*      uu$$$$$$
u$$$$$$$$$$$$      *****     uuuu$$$$$$$$$
$$$$***$$$$$$$$$$$uuu   uu$$$$$$$$$$***$$$*
 ***      **$$$$$$$$$$$$uu **$***
          uuuu **$$$$$$$$$$$uuu
 u$$$uuu$$$$$$$$$$uu **$$$$$$$$$$$$uuu$$$
 $$$$$$$$$$****             **$$$$$$$$$$$$*
   *$$$$$*                        **$$$$**
     $$$*      PRESS ANY KEY!       $$$$*
```

Top defence tips

'Most people only start doing backups when they have lost data' Simon Edwards noted, before giving his top tips:

- Keep your computer system up to date, by downloading all software updates as soon as they are offered
- Use anti-malware software, not just what comes free from Microsoft. (Some of the free solutions on offer are free because they protect against nothing, added Grebennikov.)
- Carefully check the email address of anything suspicious, in case it differs slightly from an address you think you know
- Don't immediately click on every link you are sent or offered
- Don't immediately click OK for every pop-up that appears on screen
- Most important; when you back up files keep multiple copies. Don't keep over-writing the same name file with new versions. Ransomware can take hours or days to encrypt the files on a PC, depending on how many files you have got, so you may find your backup copy is infected.

Simon Edwards also made a prediction. Children playing console games or families watching Smart TVs will be the next easy targets for ransomware.

'We have already seen reports of a family who downloaded an app to watch a movie. A law enforcement-themed screen locker then appeared. Removing the malware from the TV was hard, requiring an undocumented factory reset. Symantec research has reported on how such a thing can work and how difficult it is to remove. I believe this is only going to get worse because people will pay, the chances of the

Russians takes the fight to ransomware *continued*

attackers being caught are low and it's probably not that hard (technically) to launch the attacks'.

'Smart TV and games console infection will most likely come from downloading a trap game or app' says Simon Edwards. 'It may be a phoney version of a genuine game, and perhaps even offer some limited gameplay. Or infection may come from a home network which includes some low-price Internet of Things device like a security camera or even a lamp, which does not use a password and has poor security. People don't realise their homes are networked and vulnerable. The bad guys can now even send data to a cloud store, which infects other stored material.'

'Once the ransomware has got code on a machine it will schedule encryption for a particular time on a particular day. I foresee children being targeted on Christmas morning while they are watching TV or playing the new game they have just got as a present. If they want to carry on watching or playing their parents will have to pay $50 or so. The bad guys even provide help lines to tell people how to pay a ransom in bitcoin. One even extended the time to pay for an old lady with an encrypted PC who was having difficulty paying.'

'And now that robots are in more and more homes there is a new nightmare scenario; they could be programmed to attack their owners.',

Acronis True Image costs £79 for a year's use of 1TB Acronis cloud storage, with users able to choose between several countries where their data can be stored. The software can be used with PCs or Macs, but not yet TVs or games machines.

New PicoScope designed for differential waveforms

Pico Technology has launched the PicoScope 4444 high-resolution differential oscilloscope. This instrument features four true differential input channels and a range of accessories for measurements from millivolt to 1000V CAT III applications. The new PicoScope addresses the problem of making accurate voltage waveform measurements on circuit elements that are not ground-referenced, without the risk of short circuits that could damage the device under test or the measuring instrument.

'The PicoScope 4444 enables engineers to make differential voltage measurements in the presence of common-mode signals,' said Trevor Smith, Business Development Manager, Test & Measurement, at Pico Technology. 'The new instrument has 14-bit resolution on four channels and 256 megasample capture memory, so is ideal for precise analysis of complex waveforms ranging from biomedical sensors to current probes and 1000V CAT III power distribution circuits.'

The new scope has a novel intelligent probe interface that, in addition to delivering the differential signal to be measured, can also provide power for active probes such as Hall-effect AC/DC type active current probes. The scope detects when a compatible probe is connected and sets the corresponding units and vertical settings in the PicoScope 6 software.

Pricing and availability

Prices for a kit, with a PicoScope 4444, three PicoConnect 441 differential 1:1 probes and a TA271 D9-BNC adaptor start at £1,075. More details available at: **www.picotech.com**

Farnell element14 Lab Makeover competition

Farnell element14 has announced a 'Win a Lab Makeover' competition for education organisations in the UK, giving them the opportunity to have their teaching space refurbished.

Schools, universities and other education charities are being invited to submit their establishment to be considered for a lab makeover worth up to £3,500. Farnell element14 has also partnered with Keysight to support the competition by giving away five InfiniVision 1000 X-Series Oscilloscopes worth over £600 each to the winning organisation to be used in their newly refurbished lab space.

The closing date for entries is 18 April – for more details, visit: **http://uk.farnell.com/lp-win-a-lab-makeover**

HPS140MK2 hand-held scope

Belgian innovator and electronics developer Velleman has released its latest hand-held pocket scope – the HPS140MK2, with a white O-LED display.

Although small in size, the HPS140MK2 has a bandwidth of up to 10MHz and packs 40Ms/s in real time. The scope's sensitivity can go as low as 0.1mV with full auto-range option, memory hold function and signal markers for amplitude and time. This powerful device can run for up to eight hours on four AAA alkaline batteries. Further details available at: **www.esr.co.uk**

Lithium-ion battery inventor does it again!

A team of engineers led by 94-year-old John Goodenough, professor at The University of Texas at Austin and co-inventor of the lithium-ion battery, has developed the first all-solid-state battery cells that could lead to safer, faster-charging, longer-lasting rechargeable batteries for handheld devices, electric cars and stationary energy storage.

Today's lithium-ion batteries use liquid electrolytes to transport lithium ions between the anode and the cathode. If a battery cell is charged too quickly, it can cause dendrites (metal whiskers) to form and cross through the liquid electrolytes, causing a short circuit that can lead to explosions and fires. Instead of liquid electrolytes, the researchers rely on glass electrolytes that enable the use of an alkali-metal anode without the formation of dendrites.

The new cell has at least three times the energy density of today's lithium-ion batteries. A battery cell's energy density gives an electric vehicle its driving range, so a higher energy density means that a car can drive more miles between charges. The new battery also allows for a greater number of charging and discharging cycles, leading to longer-lasting batteries, as well as a faster rate of recharge (minutes rather than hours).

Coffee & Tea
Café
Brew Over Ice
Coffee
Strong
Tea/Other
Hot Cocoa
8 oz
Current Outside
78°
Cloudy
72°
80°
74°
23% Humidity
ALARM SYSTEM
1 2 3
4 5 6
7 8 9
* 0 #

High Impact Embedded Graphics GUI Design Has Never Been This Simple

Free Visual Design Tools & Graphics Libraries for Your GUI Applications

72°F
-02°F
32°F
78°
74°

Microchip offers an industry leading complement of comprehensive visual Graphical User Interface (GUI) development tools, software graphics libraries and hardware tools for all your 32-bit graphics needs.

Our graphics solutions are supported with the free MPLAB® Harmony software framework and offers developers the choice of two best-in-class tools:

① Our MPLAB® Harmony Graphics Composer works in conjunction with our MPLAB Harmony Graphics Library to help you generate professional looking GUIs without writing a single piece of code!

OR

② You may choose SEGGER emWin Pro as your graphics library and take advantage of its expansive list of widgets and the SEGGER toolchain.

Multimedia Expansion Board II (DM320005-2)

Get started today by downloading training material, documentation and tools!

microchip DIRECT
www.microchipdirect.com

MPLAB® HARMONY

MICROCHIP

www.microchip.com/MCU32GFX

The Microchip name and logo, the Microchip logo and MPLAB are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2017 Microchip Technology Inc. All rights reserved. DS60001462A. MEC2138Eng01/17

Questionable gratification, strange science

TechnoTalk

Mark Nelson

We do technical hobbies for enjoyment and pleasure, right? Or are they really a kind of masochism, or perhaps worse, a kind of self-imposed act of penance? And now, to help us absorb even more misery, there's a new reason why projects fail to work. Mark Nelson explains with the aid of Belgian vote-counting technology.

IN A RECENT ISSUE OF TRADE magazine *ERT* (you may remember this publication as *Electrical and Radio Trading*) an industry giant argued that shops would sell more Hi-Fi if they placed more focus on the fun factor. Darrell Huggins, group chief executive of Chinese manufacturer IAG, which owns classic British Hi-Fi brands Wharfedale, Quad and Mission, was emphatic. 'I think it should be fun. We need to show our enthusiasm – and project that to consumers. The fun thing now is that there's so much music available in so many different formats – there are more people listening to music now than ever. It's fantastic for the whole industry,' he declares.

Been there, got the tee shirt...

I admire his optimism and of course I too am an evangelist for all things electronic. Any new gadget, I want to check it out; after all that's why they invented the phrase, 'Hope springs eternal'. But how long before the good feeling wears off and you feel a yen for something more expensive? In the end it becomes an addiction, regardless of whether we are talking about consumer electronics, homebrew electronic projects, amateur radio or high-performance computers. 'So what?' I hear you say. Quite right. I must stop being a misery and get on with the main business of this article, which is to impart valuable information for improving the success of your electronic constructions.

Making wrong things right

As all practical electronicists know, the more useful or mission-critical an electronic device is, the greater the likelihood that it will fail at a time of extreme criticality. In the past, we blamed it on dirty electricity or an unsuspected build-up of smoke pressure inside some active or passive component that had to be released – sooner or later. Unclean electrons are hard to detect, but a healthy release of smoke (accompanied by an acrid smell) makes faultfinding straightforward. Not so easy to fix is random misbehaviour in digital electronics, with no evidence of component failure, over-voltage or thermal runaway. But a press announcement from an eminent academic institution has revealed a new failure mode: cosmic-ray attack. And no, this was neither an April Fool's prank nor a fake news report from the easily bamboozled media across the Pond.

As the weekly research newsletter of Vanderbilt University in the US explained a few weeks ago, alien particles from outer space are wreaking low-grade havoc on electronic devices. You can curse and blame the failure on substandard components, yet in many instances these operational failures may be caused by the impact of electrically charged particles generated by cosmic rays that originate outside the solar system. Stupid nonsense?

Not according to professor Bharat Bhuva of the university's electrical engineering department. 'This is a really big problem, but it is mostly invisible to the public,' he told the annual meeting of the American Association for the Advancement of Science on 17 February. 'When cosmic rays travelling at fractions of the speed of light strike the Earth's atmosphere they create cascades of secondary particles, including energetic neutrons, muons, pions and alpha particles. Millions of these particles strike your body each second. Despite their numbers, this subatomic torrent is imperceptible and has no known harmful effects on living organisms. However, a fraction of these particles carry enough energy to interfere with the operation of microelectronic circuitry. When they interact with integrated circuits, they may alter individual bits of data stored in memory. This is called a "single-event upset", or SEU.'

Bit flipping

Since it is difficult to know when and where these particles will strike and they do not do any physical damage, the malfunctions they cause are very difficult to characterise. As a result, determining the prevalence of SEUs is not easy or straightforward. Bhuva continued: 'When you have a single bit flip, it could have any number of causes. It could be a software bug or a hardware flaw, for example. The only way you can determine that it is a single-event upset is by eliminating all the other possible causes.'

Incidents attributed to cosmic bit flipping include a local election in Belgium during which an electronic voting machine added 4,096 extra votes to one candidate. The error was detected only because it gave the candidate more votes than were possible, and it was traced to a single bit flip in the machine's register. A number of unexplained glitches in airliner computers – some of which experts feel must have been caused by SEUs – have resulted in cancellation of hundreds of flights resulting in significant economic losses.

Causes for concern and reasons to be cheerful

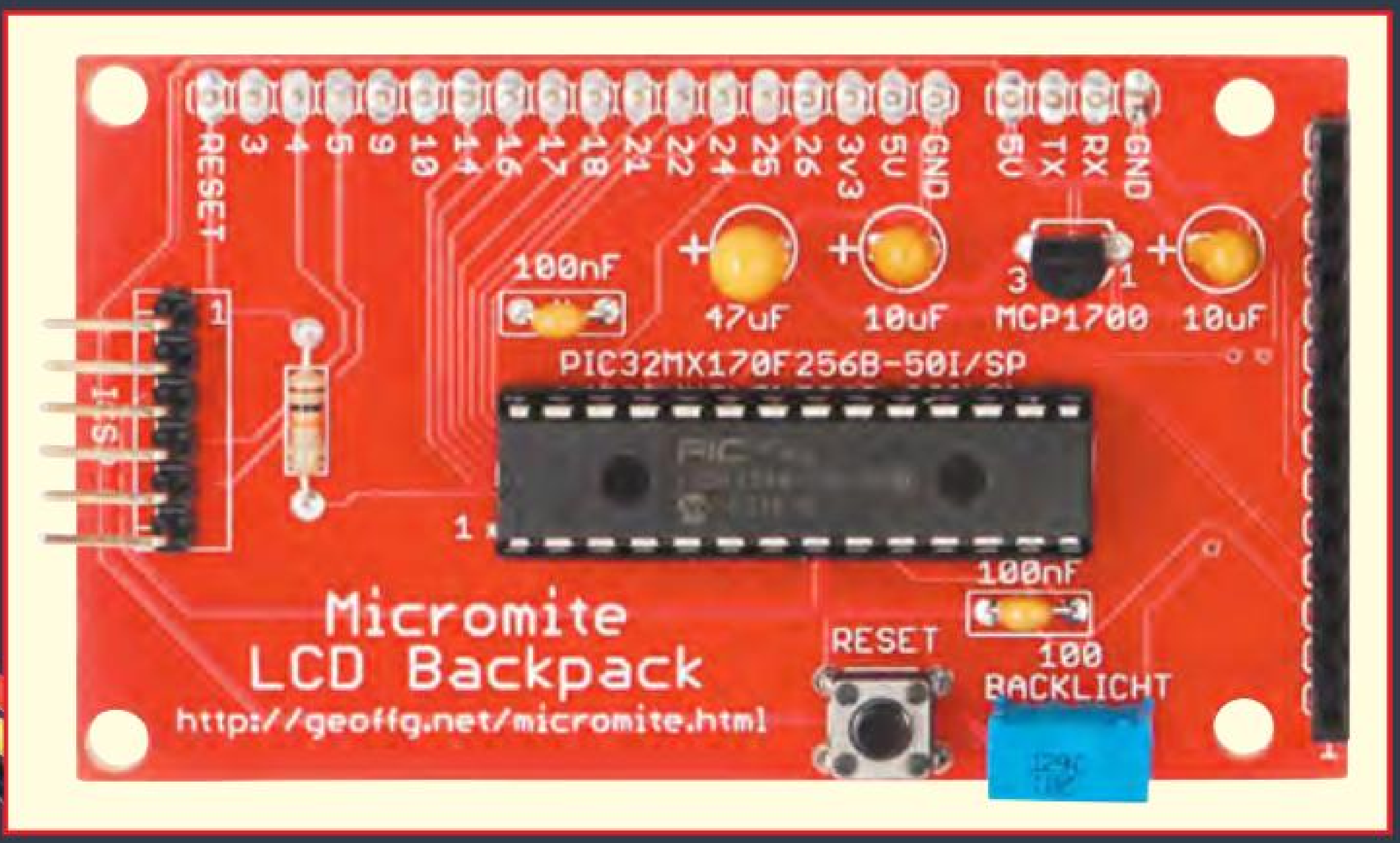
As transistor sizes have shrunk, they have required less and less electrical charge to represent a logical bit. So the likelihood that one bit will 'flip' from 0 to 1 (or 1 to 0) when struck by an energetic particle has been increasing. What's more, it's impracticable to shield microelectronics from these energetic particles. For example, it would take more than three metres of concrete to keep a circuit from being zapped by energetic neutrons. However, there are ways to design computer chips to dramatically reduce their vulnerability. For situations where reliability is absolutely critical, you can simply operate processors in triplicate and compare their outputs. 'The probability that SEUs will occur in two of the circuits at the same time is vanishingly small. So if two circuits produce the same result it should be correct,' said Bhuva. The good news, he added, is that the aviation, medical equipment, IT, transportation, communications, financial and power industries are all aware of the problem and are taking steps to address it. 'It is only the consumer electronics sector that has been lagging behind in addressing this problem,' he concluded.

The Micromite LCD BackPack

...add a touch-screen LCD to your next project

By Geoff Graham

EGT
46
CHT
46
OIL
46
AMP
35
OAT
26
VOLT
49



The *Micromite LCD BackPack* combines a full-colour touch-sensitive LCD panel with a low-cost 32-bit microcontroller running a BASIC interpreter. It packs an incredible amount of power at an amazingly cheap price and will leave you thinking up project after project where you could put it to good use.

AS ANYONE with a smartphone or tablet is keenly aware, a touch-sensitive colour graphics LCD is the primary input and output interface for a whole range of products. These include not only smartphones and tablets but also air-conditioners, vehicle controls and GPS units, plus simpler devices such as coffee makers. Using the LCD screen, the user can clearly see what the product is doing and by using the touch screen, they can set options and control the device's operation.

So, wouldn't it be great to have the same capability in your next creation? Well now you can, with the *Micromite LCD BackPack*. It's based on the Micromite Mk2 microcontroller running a BASIC interpreter and a 240 × 320 pixel colour LCD panel with a touch-sensitive interface. The LCD panel can be purchased on eBay for less than a tenner and by adding the low-cost Micromite and a few other components, you have a complete controller/display package.

By using the easy-to-learn BASIC programming language, you can create a professional graphical interface for your next creation, be it a reticulation controller, battery monitor, temperature controller or some other project that you probably haven't thought of yet. With just a few lines of BASIC, you can display text and draw graphs and symbols. The touch-sensitive input can be queried from within BASIC, so the display is all you need to use and control the gadget. It really is that easy! Plus, it's easy to build, uses just a few parts and costs less than £20. What are you waiting for? Start creating!

The Micromite

We introduced the remarkably cheap, powerful and easy-to-use Micromite (Mk2) in the previous three issues. It uses a low-cost 32-bit PIC32 microcontroller running a Microsoft-compatible BASIC interpreter called MMBasic.

The BASIC language used by the Micromite is fun and easy to use, yet provides a rich and powerful set of commands. It has the ability to detect logic signals (ie, on/off) as well as measure voltages, frequency, temperature, humidity and more. Other

Features and Specifications

- Colour TFT LCD with 320 × 240 pixels, 65,536 colours, and 2.2-inch, 2.4-inch or 2.8-inch diagonal measurement.
- Touch-sensitive screen with the touch coordinates reported in pixels.
- Microchip 32-bit 48MHz microcontroller with 256KB Flash memory and 64KB of RAM.
- 11 input/output pins. All can operate as digital input/outputs and four can operate as analogue inputs. Three additional I/O pins for SPI use.
- Digital I/O sink or source capability of 15mA.
- MMBasic interpreter with 59KB program space and 53KB RAM (for variables and other uses). Programs can be 2500 lines or more in size.
- Graphic commands include CLS, PIXEL, LINE, BOX, RBOX, CIRCLE, TEXT and BITMAP, using any of the 65,536 colours.
- Communications protocols include I^{2}C, asynchronous serial, RS232, IEEE 485, SPI and 1-Wire.
- Built in support for IR remote controls, temperature and humidity sensors, distance sensors, numeric keypads and battery-backed clocks.
- Power supply: 4.5V to 5.5V.
- Current drain: 175mA at normal screen brightness; 225mA at full brightness (40MHz CPU speed).
- Dimensions: 50 × 86 × 27mm for 2.8-inch LCD; 45 × 77 × 27mm for 2.4-inch LCD.

functions include an infrared remote control input, support for numeric keypads and an in-built clock.

Programs are stored in the chip's internal Flash memory and can be edited on the Micromite using its in-built full screen editor, via a serial interface. A program can be configured to run immediately on power up, so that the Micromite acts as a pre-programmed custom chip and the user need not know anything about what is running inside.

A powerful feature of the Micromite is the range of communications protocols that it supports. These include I^{2}C, asynchronous serial, RS-232, IEEE 485, SPI and 1-Wire. These can allow your program to communicate with other chips and sensors and to send data to test equipment. The 28-pin Micromite used in the *LCD BackPack* has 11 spare input/output pins, so there is plenty of capability for controlling and interacting with the outside world.

ILI9341-based LCD panel

The ILI9341 is a graphics LCD controller that is often referred to as a COG device (controller on glass). This means that the controller chip is bonded directly to the glass substrate used for the LCD. LCD panels using this technique are manufactured in very large numbers for use in common consumer products such as microwave ovens and refrigerators. As a result, they are startlingly cheap. You can find them on eBay for under a tenner and that often includes free shiping.

This is incredible value considering what you get, especially when compared to the old standby for DIY microcontroller projects, the tiny 2-line 16-character LCD module. That's now so 'last century'!

The display supported by the Micromite has 270 × 340 pixels, 65,536 colours and comes in three different sizes – 2.2 inch, 2.4 inch and 2.8 inch diagonal. Most versions also have a built-in resistive touch controller, so you can draw buttons and symbols on the screen and users can then select these by simply touching the screen.

MMBasic 5.1

The latest version of MMBasic used by the Micromite Mk2 includes many improvements, but the stand-out feature is its support for ILI9341-based LCD panels. There are six basic commands that interact with the display, the simplest being `PIXEL`, which allows you to set a single pixel to any one of 65,536 colours. You can also draw lines with the `LINE` command, circles with the `CIRCLE` command and boxes with the `BOX` command. These commands have many options; for example, you can control the width and colour of the lines as well as the colour used to fill boxes and circles.

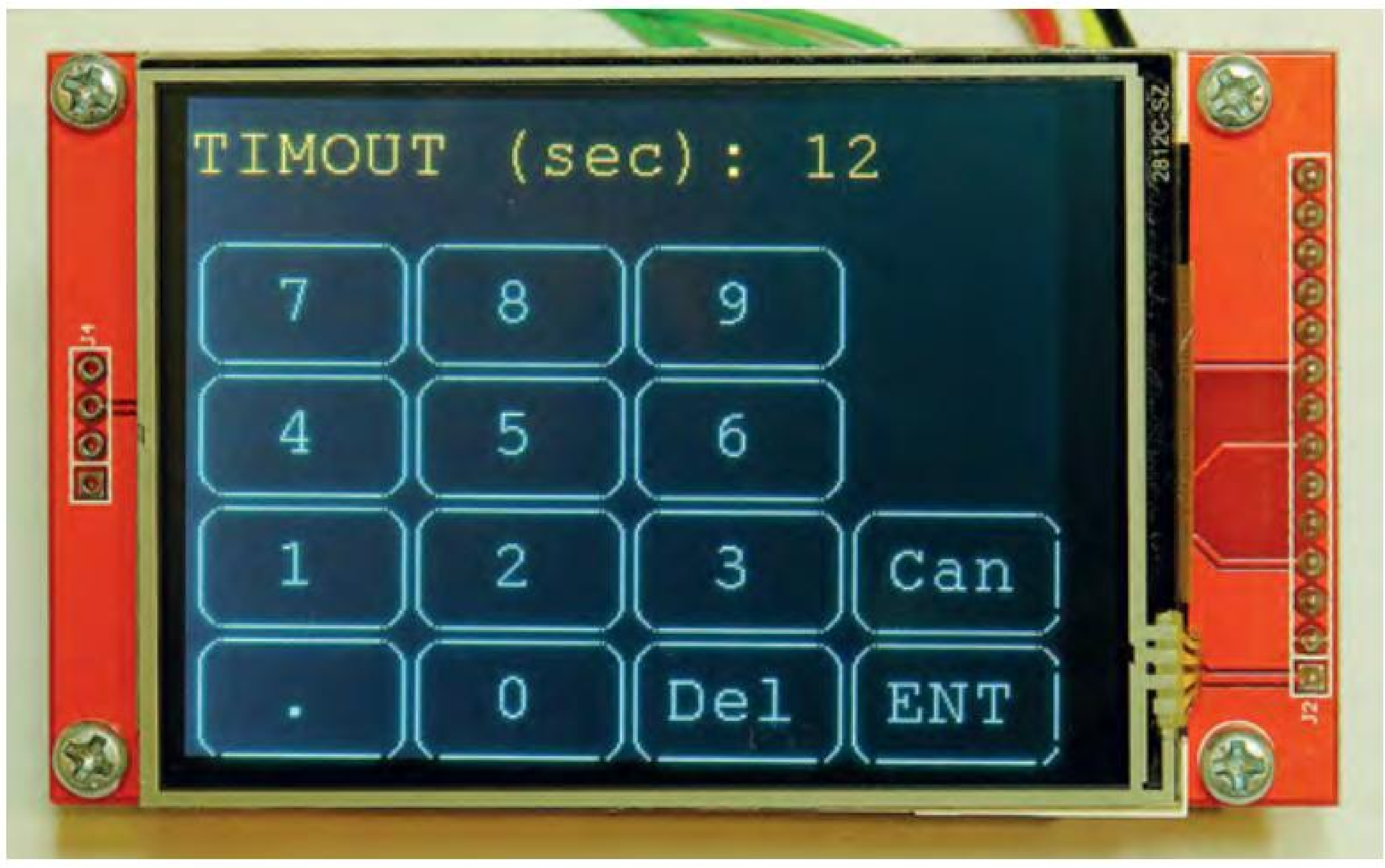
The `TEXT` command will display text in any position on the display panel in the same 65,536 colours. More than a dozen fonts are available, ranging from tiny to large, and these include graphical icons which can be used to liven up the display.

Most cheap LCD panels also have a resistive touch screen and MMBasic 5.1 includes full support for detecting a touch on the screen via the `TOUCH()` function. This will return the `X` and `Y` coordinates (in pixels) of where the screen is touched so that your program can react accordingly.

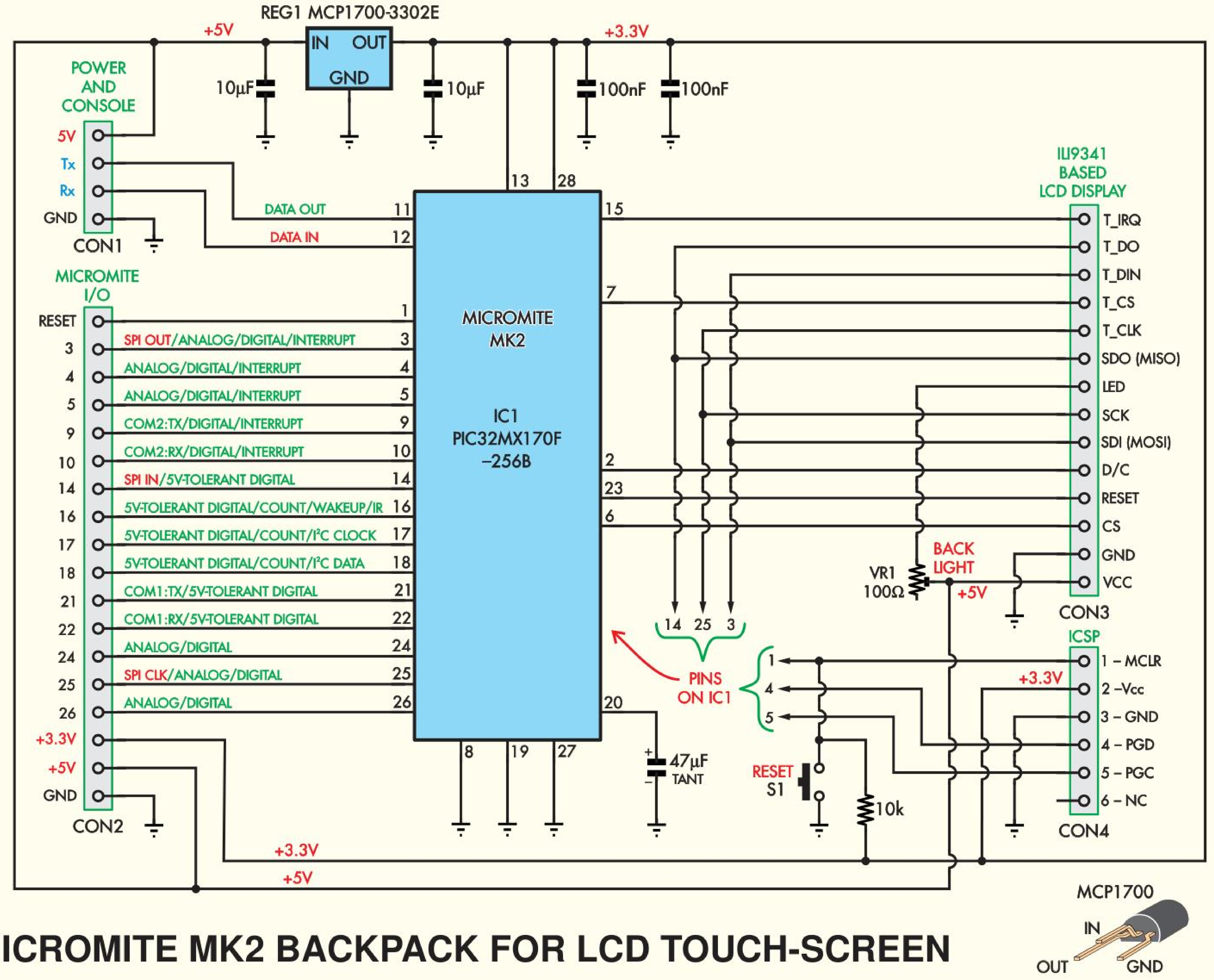
Using the drawing commands, you can draw a button on the screen and then monitor the touch function to see if that button has been pressed. The touch feature is so convenient that you will be able to dispense with physical switches and knobs in many projects.

Micromite LCD BackPack

The *Micromite LCD BackPack* brings all three of these elements together. It is a small PCB that is designed to



The *Micromite LCD BackPack* incorporates graphic drawing capabilities with touch sensitivity, so it's easy to use it as a user input/ output interface in a project. In this case, the display shows a keypad which can be used to enter a number.


REG1 MCP1700-3302E
+5V
IN
OUT
GND
+3.3V
POWER AND CONSOLE
10µF
10µF
100nF
100nF
5V
Tx
Rx
GND
CON1
DATA OUT
DATA IN
MICROMITE I/O
RESET
SPI OUT/ANALOG/DIGITAL/INTERRUPT
ANALOG/DIGITAL/INTERRUPT
COM2:TX/DIGITAL/INTERRUPT
COM2:RX/DIGITAL/INTERRUPT
SPI IN/5V-TOLERANT DIGITAL
5V-TOLERANT DIGITAL/COUNT/WAKEUP/IR
5V-TOLERANT DIGITAL/COUNT/I²C CLOCK
5V-TOLERANT DIGITAL/COUNT/I²C DATA
COM1:TX/5V-TOLERANT DIGITAL
COM1:RX/5V-TOLERANT DIGITAL
ANALOG/DIGITAL
SPI CLK/ANALOG/DIGITAL
CON2
MICROMITE MK2
IC1 PIC32MX170F –256B
47µF TANT
ILI9341 BASED LCD DISPLAY
T_IRQ
T_DO
T_DIN
T_CS
T_CLK
SDO (MISO)
LED
SCK
SDI (MOSI)
D/C
RESET
CS
GND
VCC
CON3
BACK LIGHT
VR1 100Ω
PINS ON IC1
ICSP
1 – MCLR
2 –Vcc
3 – GND
4 – PGD
5 – PGC
6 – NC
CON4
RESET S1
10k
MCP1700
IN
OUT
GND

MICROMITE MK2 BACKPACK FOR LCD TOUCH-SCREEN

Fig.1: the *Micromite LCD BackPack* circuit uses just 10 components, including the LCD panel. IC1 is the Micromite which does most of the work, while IC2 is a voltage regulator supplying 3.3V to IC1. There is another voltage regulator built into IC1 which supplies 1.8V for the CPU inside this IC. The 47µF capacitor on pin 20 (Vcap) stabilises this regulator and it is critical that a high-quality capacitor, such as a tantalum type, is used in this position.

piggyback on an ILI9341-based LCD panel, making a two-layer 'sandwich'. It uses just 10 components and will take less than half an hour to build.

The *Backpack* is designed so that it and its LCD panel can be plugged into a solderless breadboard with a 0.1-inch pitch. This allows interface circuitry to be tested and debugged in an easy-to-use environment. Then, once debugged, the circuit can be transferred to a custom PCB or strip board and mounted on the back of the *BackPack*, making a compact three-layer sandwich.

The accompanying photographs give some examples of what you can use the *Micromite LCD BackPack* for. We experimented with a battery monitor, digital speedometer and an engine monitor. But as you may have realised by now, the possibilities are endless.

Referring to the circuit in Fig.1, you can see that the *Micromite LCD BackPack* is about as simple as it gets. The main power input is 5V and this is used to directly power the LCD. It is also fed to a small 3-pin regulator that provides 3.3V for the microcontroller.

The microcontroller used for the Micromite is the Microchip PIC32MX170F256B. This device has a 32-bit processor running at up to 50MHz, 256KB of rewritable Flash memory and 64KB of RAM; not bad for something so cheap.

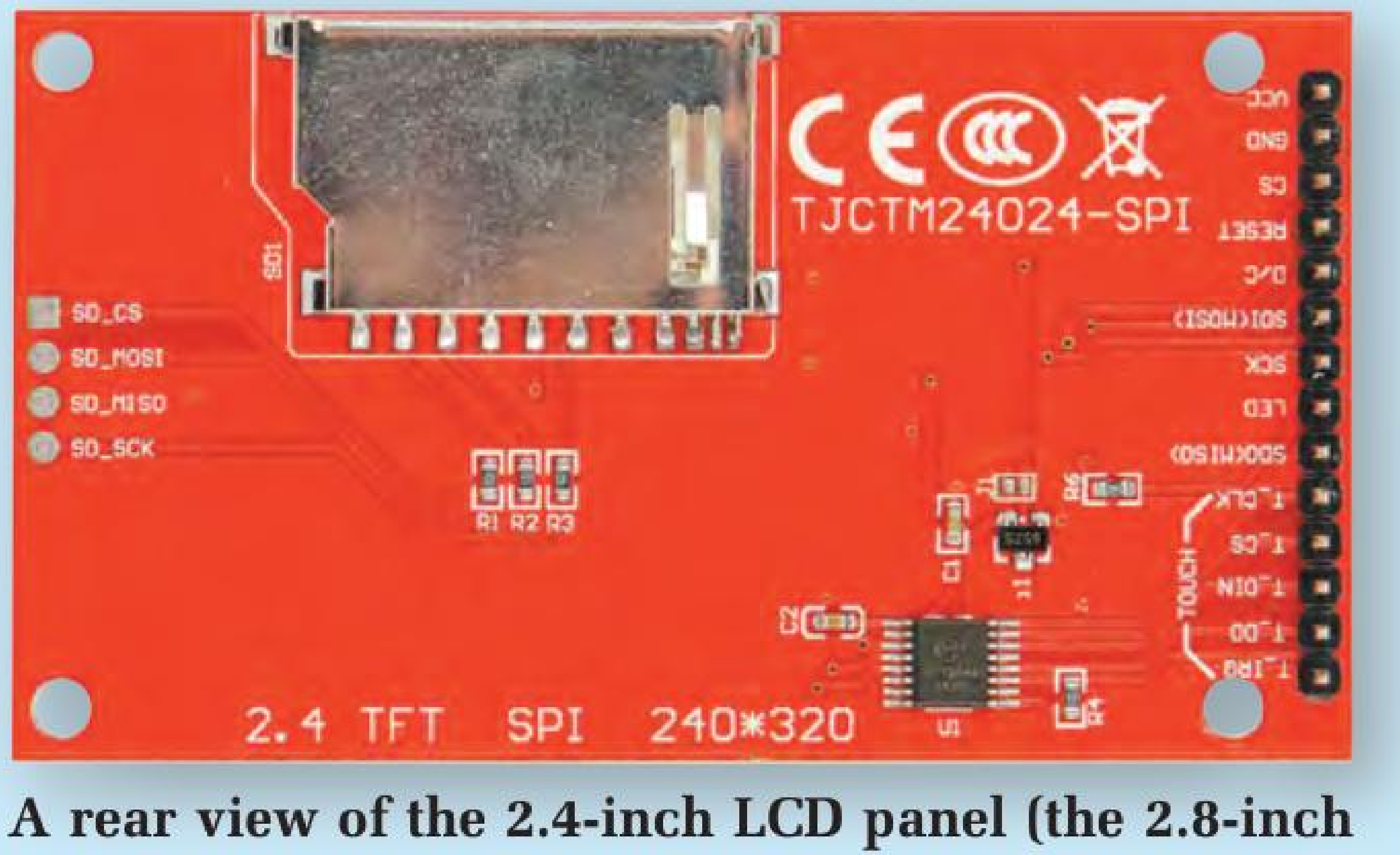
Most pins on the Micromite run to the four main connectors:

- CON1 is the power input and the console (more on that later)
- CON2 is the main I/O connector and it is here that you interface the *Micromite LCD BackPack* to the outside world
- CON3 is the connector dedicated to the ILI934-based LCD panel
- CON4 is the ICSP (In-Circuit Serial Programmer) connector. It is used to load the MMBasic firmware into a blank microcontroller. We specified a rightangle 6-pin header for this connector, as that allows a programmer such as the PICKit3 to plug into CON4 even when an LCD panel is attached.

The only other components of note are S1, which is a small pushbutton used to reset the processor, and R1 which is a 100Ω trimpot that's used to adjust the brightness of the LCD's backlight. R1 is in series with the power to the backlight LEDs, so it limits the current drawn by them and therefore the brightness.

Note that the LCD panel also has a 3.9Ω resistor in series with the backlight so you will not burn out the

This view shows the 2.8-inch touch-screen LCD panel. The 2.4-inch panel is slightly smaller but is otherwise virtually identical in appearance. Both display sizes will plug into either *BackPack* PCB and will work perfectly. The only issue with a mismatched display and *BackPack* PCB is that a special physical mounting arrangement would be required.



A rear view of the 2.4-inch LCD panel (the 2.8-inch panel looks the same except for its slightly larger dimensions). Note the 16-pin touch controller chip to the bottom right. There are a number of different displays on the market so make sure that the display you purchase matches this photograph to ensure that it is compatible with the *Micromite LCD BackPack* PCB.

backlight if you wind R1 all the way down to 0Ω.

Sourcing the LCD panel

As stated, the ILI9341-based LCD panels come in three sizes: 2.2-inch (56mm), 2.4-inch (61mm) and 2.8-inch (71mm) diagonal. **Generally, the 2.2-inch display does not have a touch-sensitive screen, while the 2.4-inch and 2.8-inch displays do.** The display also includes an SD card socket, but that is not supported by the Micromite Mk2 due to memory limitations.

The best place to find a suitable display is on eBay but other online markets such as Alibaba also have them, as well as some online retailers. There are many variations on offer, so make sure that the display that you purchase matches the photographs in this article. This is important – the Micromite has been extensively tested with the photographed displays so you can be sure that they will work.

Other features to look out for in a compatible display are a red PCB, a resolution of 240 × 320 pixels and an SPI interface. Often, the description will emphasise that the display is for use with the Arduino but that is *not* relevant; they work just as well with the Micromite.

On eBay, the best way to find a suitable display is to search for the phrase 'ILI9341 LCD'. You should find many displays ranging in price from US$6 upwards. **Note that there are some 2.4-inch displays on the market that omit the touch sensitive controller** – if you need that feature, then make sure that it is confirmed in the seller's description.

Because the 2.2-inch display does not normally include a touch panel we did not design a PCB for that size but we did design separate PCBs for the 2.4-inch and 2.8-inch displays. The only difference between the two boards is that their dimensions and mounting holes match the corresponding display; otherwise they are identical.

All three display sizes will plug into either-sized PCB and will work perfectly. So your only issue with a mismatched display and PCB is that you will need to use a different physical mounting arrangement.

Construction

The build is quite simple, but before you commence you need to consider a few options. If you are buying a pre-programmed chip for the Micromite you could leave out CON4 – the programming connector. Also, you do not necessarily have to use an LCD panel with the *Micromite BackPack*. It could be just the Micromite that you need, and in that case CON3 can be omitted.

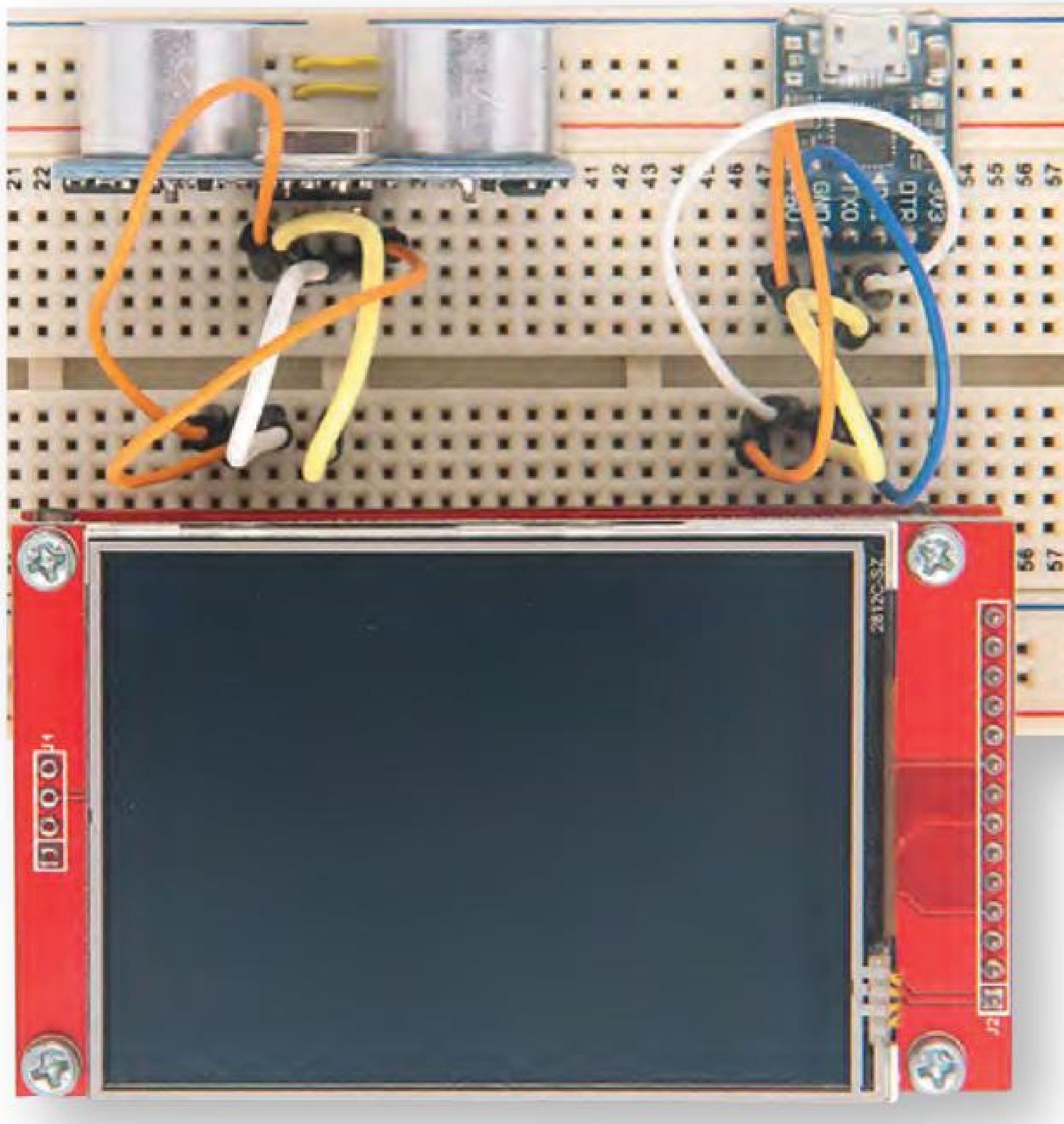
Finally, you may want to run wires directly to CON2. In that case, you can omit the pin header for that connector.

As usual, you should start construction with the low-profile components and work your way up to the bigger items such as the connectors. We recommend using a socket for IC1 as that will enable you to swap out the microcontroller if you suspect that you have damaged it.

The 14-pin female connector used for CON3 (to connect the LCD display) can be difficult to source. You can buy them on eBay or you can do what we did and cut down a longer connector to size and then use a file to smooth the rough edge so that it looks presentable.

The reset pushbutton switch (S1) can be mounted on either side of the board. Mounting it on the non-component side may make it easier to reach when you have the board and LCD panel fastened together.

Note that the 10µF and 47µF capacitors are polarised (the longer lead is the positive) so make sure that they are oriented according to the silk screen on the PCB. **The 47µF capacitor is particularly critical and must be a tantalum type, *not electrolytic*.**



The *BackPack* PCB is designed so that it can be plugged into a solderless breadboard. This allows any interface circuitry to be tested and debugged before a PCB is designed.

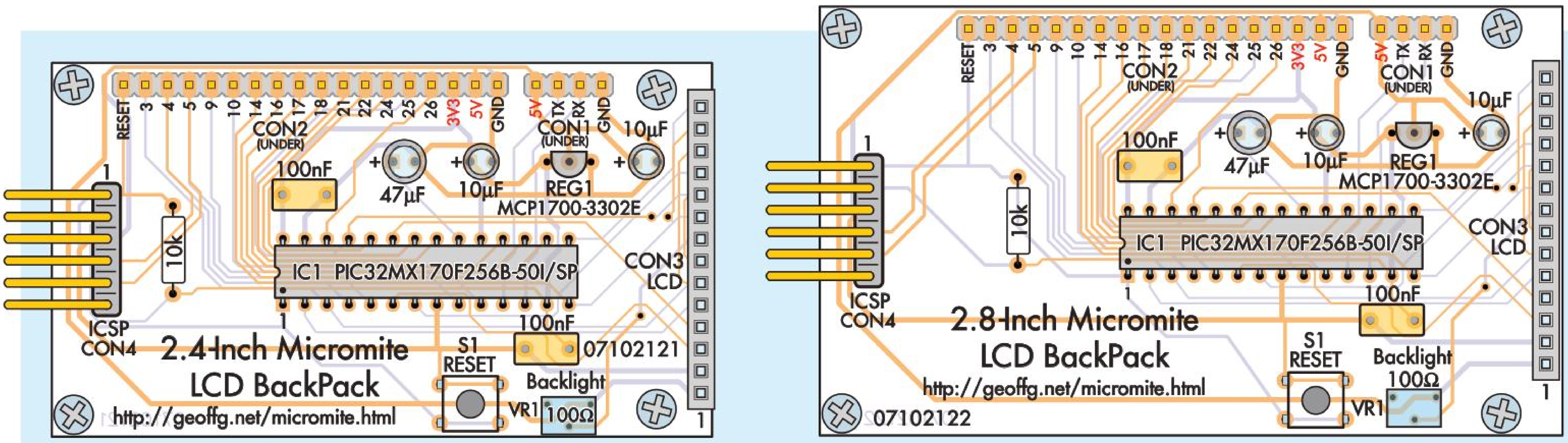


Fig.2: these two diagrams show the parts layout on the *BackPack* PCB for the 2.4-inch LCD at left and the 2.8-inch LCD at right. Note that pin headers CON1 and CON2 at the top mount on the rear of the PCB (both versions).

A multi-layer ceramic capacitor could also be used in this location, but they are generally SMD types for this sort of value. The final PCBs have provision for SMD or through-hole capacitors.

Pin headers CON1 (console + power) and CON2 (I/O pins) should be mounted on the underside (non-component) side of the board, as shown in the photos. Don't mistakenly mount them on the top of the board because they would then be impossible to reach when an LCD panel is attached.

Before you plug the microcontroller into its socket it would be prudent to apply power and check that 3.3V is across the correct socket pins and that +5V is on the correct pin on CON3. With that check made, you can remove the power and plug in IC1 and the LCD panel.

The *BackPack* PCB and the LCD panel can then be fastened together on all four corners using M3 × 12mm tapped spacers and M3 × 6mm machine screws (or, as shown in the photos, 16mm machine screws with nuts).

Be careful when handling the LCD panel. The ILI9341 controller is sensitive to static electricity and can be easily destroyed with careless handling. Make sure that you are grounded when handling the display and avoid touching the connecting pins.

Finally, if you have a blank PIC32 microcontroller, it should be programmed with the latest Micromite firmware which can be downloaded from the author's website at: **http://geoffg.net/micromite.html** (refer to the accompanying panel for the details on how to do this).

Connecting the console

In order to write and debug BASIC programs on the Micromite, you use the console. This is a serial interface running at 38,400 baud and which uses TTL signal levels. This is similar to the RS-232 interface on older computers, but the TTL signal level is inverted and swings from zero to 3.3V.

There are quite a few USB-to-serial converters on the market (see the panel below). These provide a TTL-level serial interface on one side and a USB interface on the other. When connected to a computer running Windows, Mac OS X or Linux, the converter will appear as a virtual serial port. On a Windows computer, it often appears as a high-numbered COM port, eg, COM12 or COM45.

The serial interface side of the converter will generally have a ground pin and a 5V power output pin and these can be connected to the corresponding pins on CON1 on the *Micromite BackPack*. The serial converter will then provide power to the backpack and the attached LCD, which is handy when you are editing or testing a program. If you do not need the converter (perhaps you have a working program), you should use the GND and 5V pins on CON1 as the main power input.

The USB-to-serial converter will also have two pins marked TX (or similar) for transmit and RX (or similar) for receive. **The TX pin of the serial converter must go to the RX pin**

USB-to-serial converters

There are many USB-to-serial converters on the market, ranging in price from £2-20. One of the most popular types is based on the FTDI FT232RL chip. In fact, this chip has become so popular that some companies make clones of it, even down to the markings which imitate the genuine chip.

This understandably upset FTDI and they released a new Windows device driver that not only refused to work with a clone chip but also disabled the chip so that it would not work with any other computer or driver. This driver was also included in an automatic update that Microsoft provided for Windows-based PCs, with the result that thousands of people found that their USB-to-serial converters suddenly stopped working and were worthless.

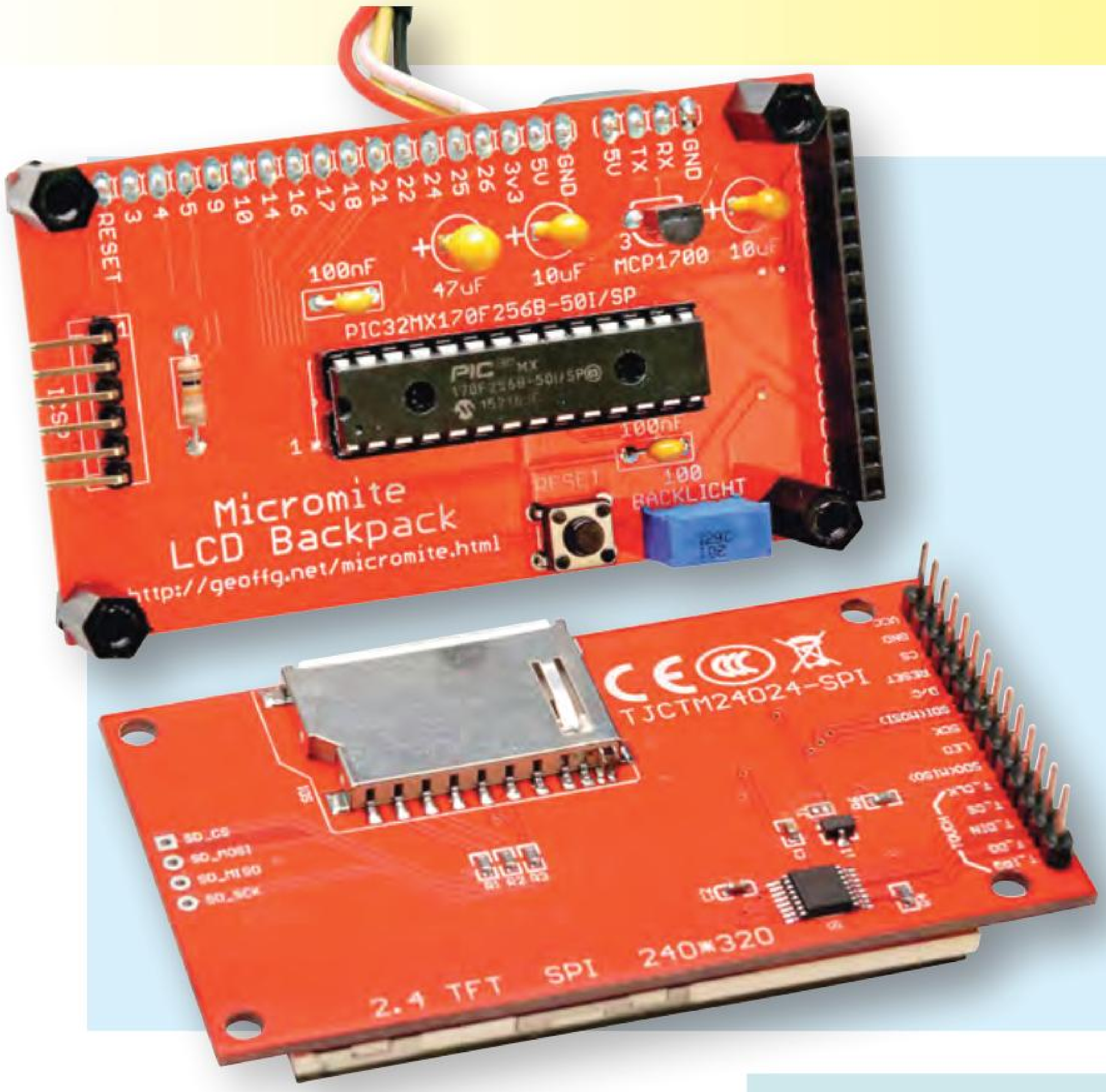
3V3
DTR
RXI
TXO
GND
+5V
SILABS CP2102

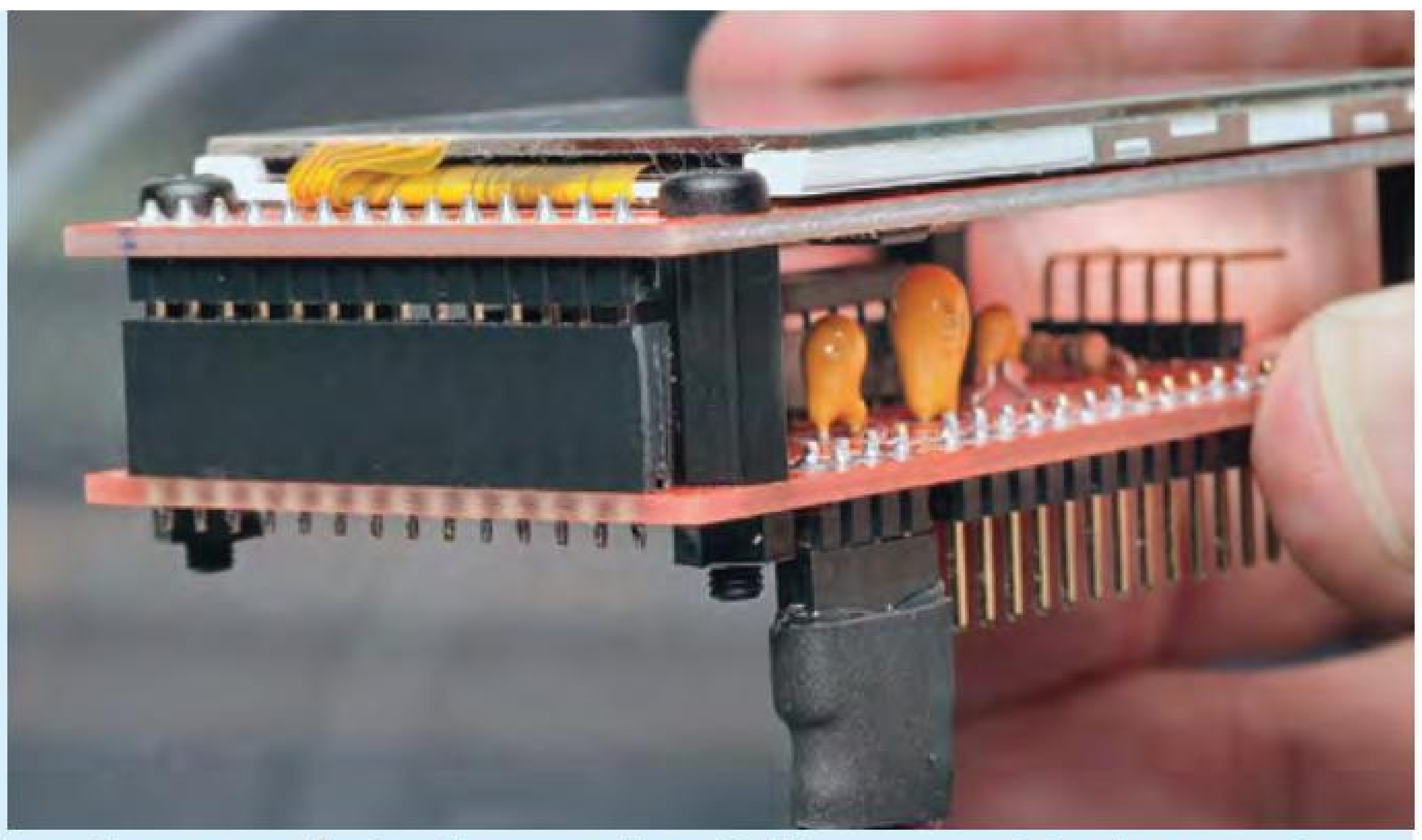
USB-to-serial converters based on the CP2102 chip can be found on eBay for just a few dollars.

The problem with this is that, at the time of purchase, there is no way of knowing if a new FT232RL-based converter uses the genuine chip or not. You will only find out when you receive the converter and try plugging it into a Windows computer.

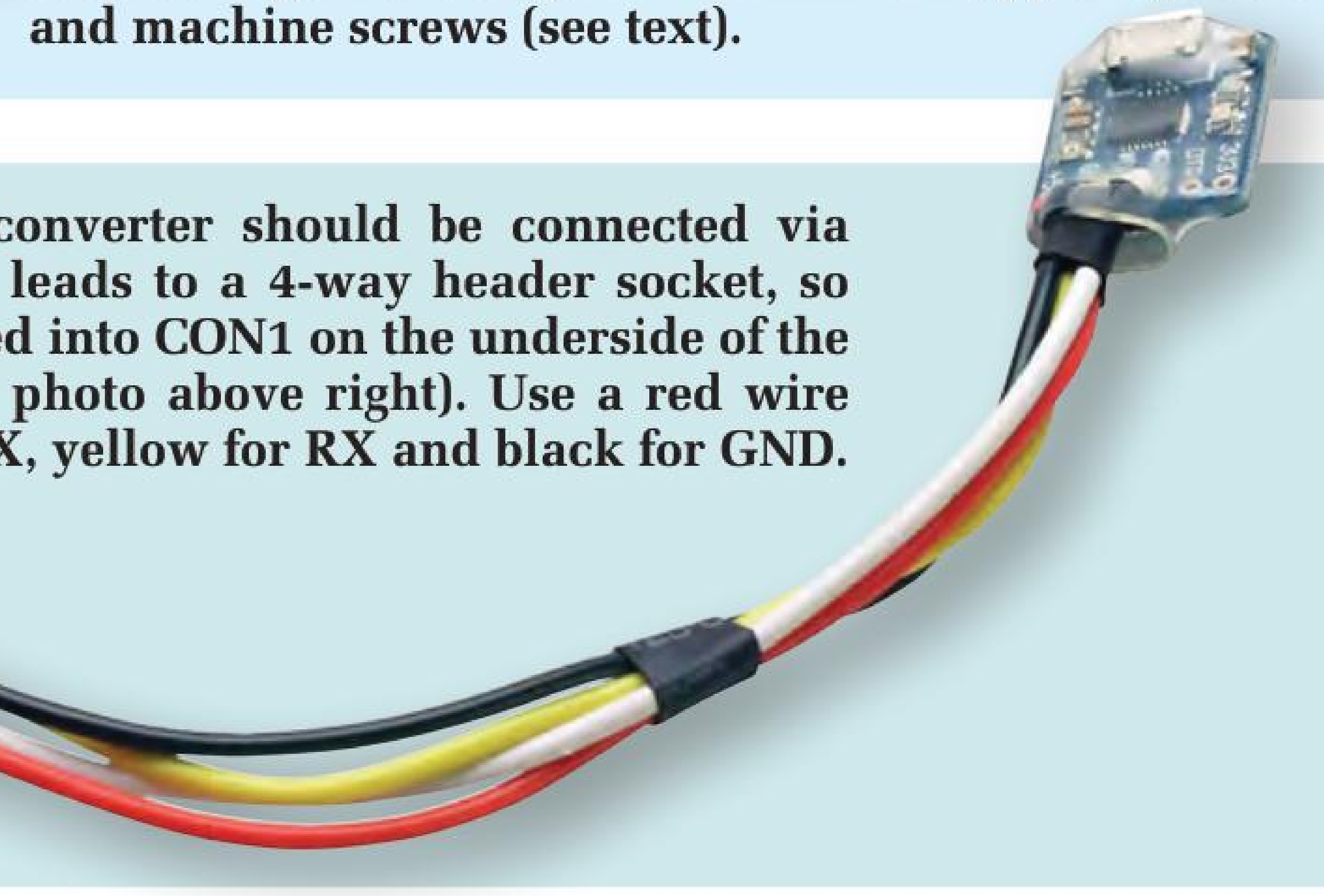
An alternative that does not carry this risk are converters based on the Silicon Labs CP2102 chip, as shown in the accompanying photograph. They can be found on eBay for a few pounds (search for 'CP2102'). We have tested them on the Micromite with both Windows 7 and Windows 10 and can report that they work just fine.

Because USB-to-serial converters based on the CP2102 are so cheap (often less than the retail price of the USB cable), you can afford to permanently connect one to the Micromite BackPack. This is handy if ever you need to come back and modify the program later.





The photo at left shows the fully assembled PCB for a 2.4-inch LCD panel (the 2.8-inch version is nearly identical). The connector to the left is for the in-circuit programmer, the connector on the right is for the LCD panel and the two on the top are for input/output and the console. The view above right shows how the LCD panel plugs into the *BackPack* PCB, with the two then secured together using M3 × 12mm untapped spacers and machine screws (see text).



The USB-to-serial converter should be connected via colour-coded flying leads to a 4-way header socket, so that it can be plugged into CON1 on the underside of the BackPack PCB (see photo above right). Use a red wire for +5V, white for TX, yellow for RX and black for GND.

of the Micromite and the RX pin must go to the TX pin. This may sound confusing but it makes sense when you think about it.

Basically, the transmit signal from the converter (the TX pin) needs to go to the receive pin (RX) on the Micromite so that the Micromite can receive data sent by the converter. Similarly, transmit from the Micromite must go to receive on the converter.

When you plug the USB side of the converter into your computer you may have to load a driver to make it work with the operating system. Once this is done you should note the port number created for the virtual serial connection. In Windows, this can be done by firing up Device Manager and checking the 'Ports (COM and LPT)' entry for a new COM port.

Terminal emulator

With this information, you can start up a terminal emulator program on your desktop computer. This program acts like an old-fashioned computer terminal where it will display text received from a remote computer and any key presses will be sent to the remote computer over the serial link.

For Windows, we recommend Tera Term version 4.88. It has a host of features and is free. It can be downloaded from **http://tera-term.en.lo4d.com/**

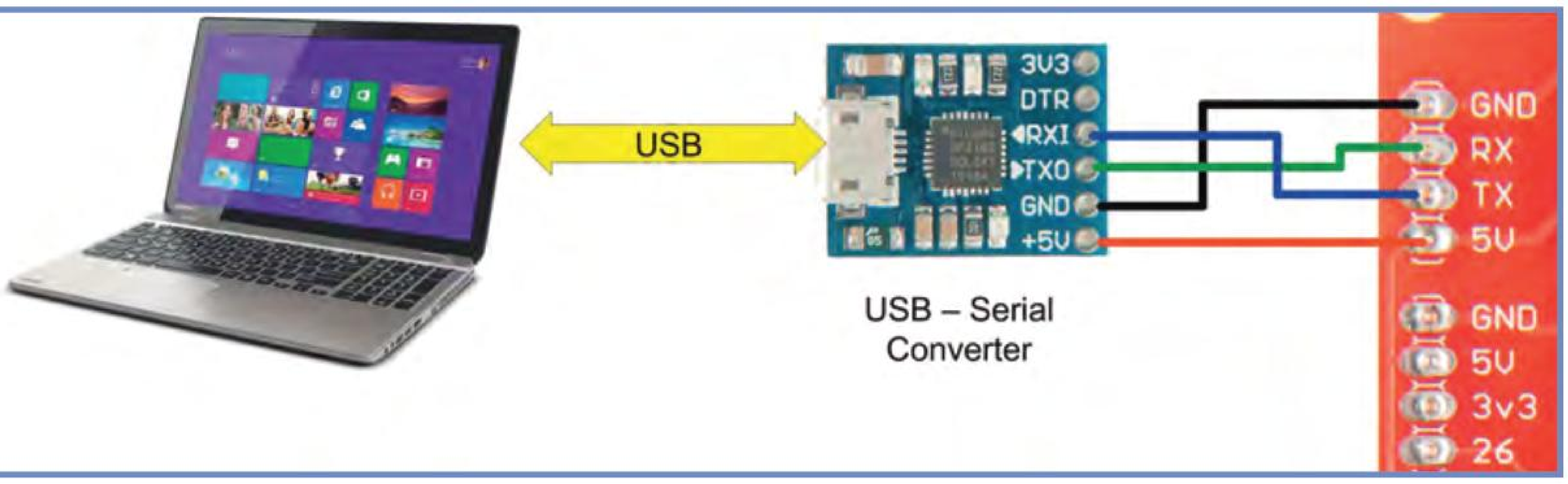
Once you have your terminal emulator running, you should configure it for the serial port number that you recorded previously and set the interface to 38,400 baud, 8 bits data, no parity and one stop bit. This is the standard used by the Micromite.

Then you can hit the Enter key on the terminal emulator and you should see the Micromite command prompt (a '>' character). If you press the reset button on the *BackPack*, you should see the full copyright banner, as shown in Fig.5.

MMEDIT

Another convenient method of creating and testing your programs is to use MMEDIT. This program was written by *SILICON CHIP* reader Jim Hiley, from Tasmania. It can be installed on a Windows or Linux computer and allows you to edit your program on your

Fig.3: the *Micromite LCD BackPack* is connected to your PC using a USB-to-serial converter. All programming and control of the Micromite is carried out via the console using a terminal emulator on the PC. Once the program is debugged and running, you can then disconnect the USB-to-serial converter.



Programming the Micromite firmware

Before you can use the Micromite, you must program it with the Micromite firmware. This can be downloaded from the author's website and includes the MMBasic interpreter which is what you need to start programming in BASIC.

The easiest option though is to purchase the chip already programmed from the SILICON CHIP Online Shop. This can either be obtained separately or as part of a kit (see parts list for further details). Alternatively, you can build the low-cost PIC32 programmer described in the Feb-Apr 2017 issues and program the chip yourself using the downloaded firmware.

Yet another option is to use Microchip's PICkit 3 programmer. This costs around £40 plus freight. The *Micromite LCD BackPack* is designed to accept the PICkit 3, even when the LCD display is attached. The accompanying photo shows just such a set-up

To use the PICkit 3, you first need to download and install Microchip's MPLAB X software development system on your personal computer. This comes in various versions for Windows, Mac OS and Linux. Unfortunately, the full install includes a lot of stuff that you don't need (such as a fully integrated development environment) but the important part is MPLAB IPE which is the programming component (IPE stands for Integrated Programming Environment). This is normally installed as an icon on your PC's desktop.

Using MPLAB IPE is reasonably intuitive. You simply select the PICkit 3 as the programmer, select the type

---

PC and then, with a single button click, transfer it to the Micromite for testing.

`MMEDIT` is easy to use, with colour-coded text, mouse-based cut and paste and many more useful features such as bookmarks and automatic indenting. Because the program runs on your PC, you can save and load your programs to and from the computer's hard disk.

It's free and can be downladed from: **www.c-com.com.au/MMedit.htm**

Driving the Micromite

The *Micromite User Manual* (available from both the *EPE* and author's website: **http://geoffg.net/micromite.html**) runs to just over 90 pages. We cannot cover that much detail here. So, the following is intended just to give you a 'flavour' of how to program the Micromite using MMBasic.

When you first connect to the Micromite with a terminal emulator you will see the command prompt, the 'greater than' symbol (>). At this prompt, you can enter almost any command in the language to test features, configure options or run a program.

For example, if you typed `PRINT 2 + 2` and then hit the enter key, MMBasic would respond with 4 and then display the prompt again. This is 'immediate mode' and is useful for testing commands and their effects.

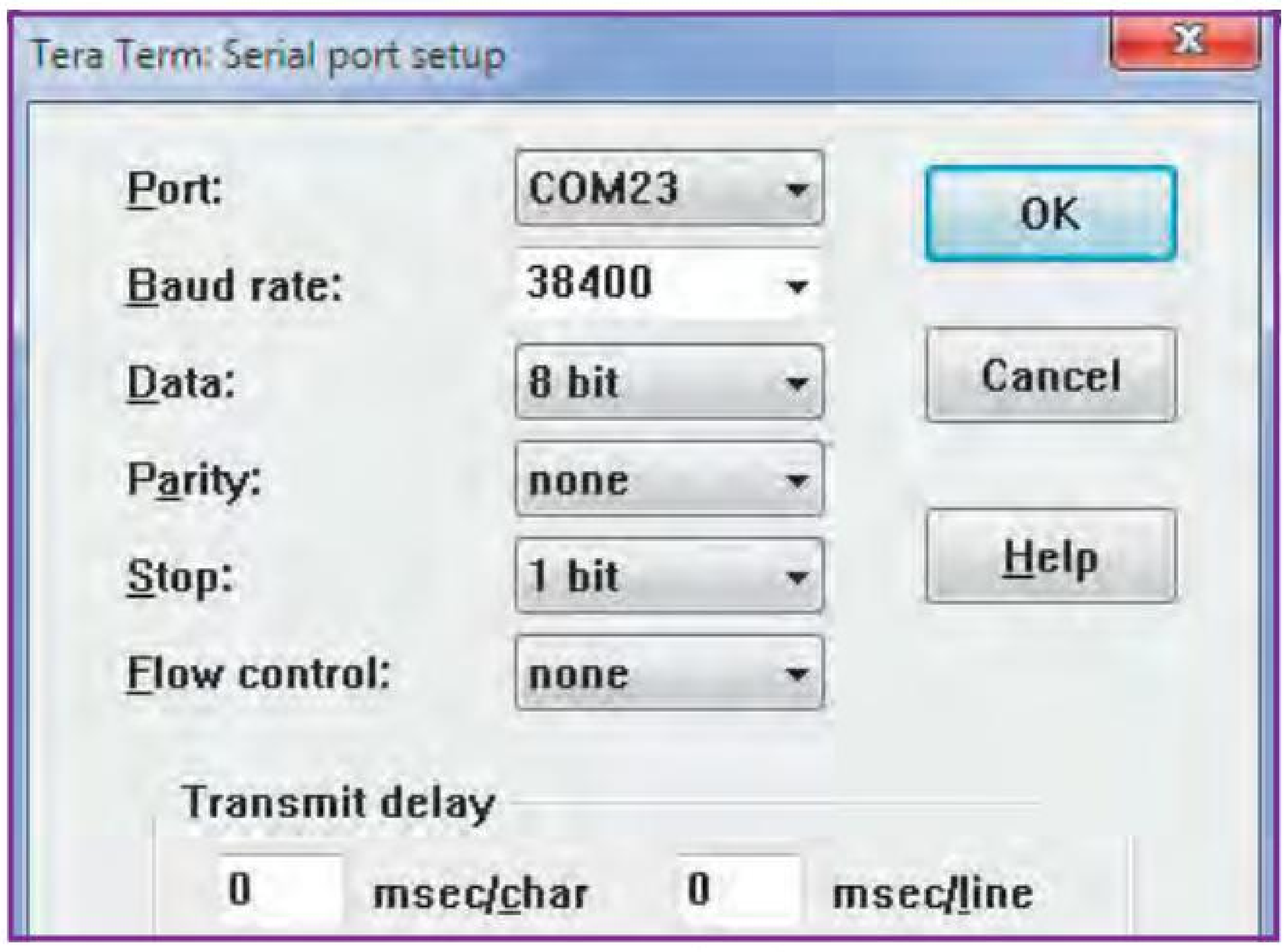
Usually, you will want to run a program that consists of more than one line and in this case there are three ways of getting your program into the Micromite. The first is by using the `EDIT` command, which will start the Micromite's built-in editor. Using the editor, you can seamlessly enter and edit programs up to the maximum size that the Micromite can handle (about 59KB).

Another way to load a program is via the `AUTOSAVE` command. This instructs the Micromite to take anything that is sent to it over the console line and save it to program memory. The `AUTOSAVE` command will terminate when a `Ctrl-z` character is received. All terminal emulators have the ability to send a file over the serial line and when the whole file has been sent you can enter `Ctrl-z` on the keyboard to signal the end of the file.

The third method is to use the `XMODEM` command on the Micromite. This will cause the Micromite to wait for an XModem transfer from the PC and then receive the program using that protocol. Many terminal emulators, including Tera Term, support the XModem protocol.

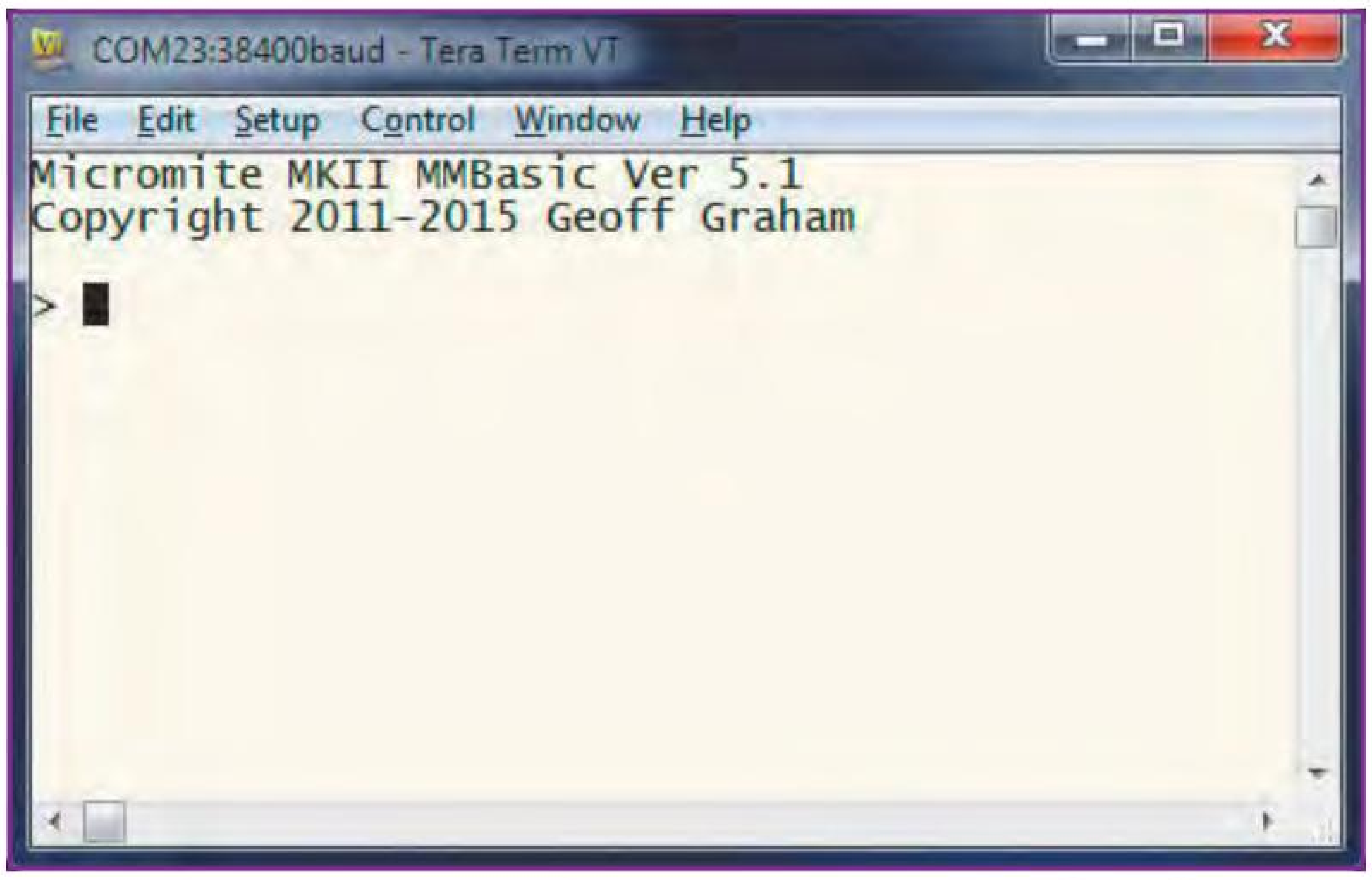
`MMEDIT` (the free editing program mentioned earlier) automates this aspect for you. It uses a combination of `AUTOSAVE` and `XMODEM` to transfer the program at the click of a button.

Inside the Micromite, the program is saved to non-volatile Flash memory. This means that you can turn the power off and the program will still be there when you reapply power. With the program in memory, you can enter



Port: COM23
Baud rate: 38400
Data: 8 bit
Parity: none
Stop: 1 bit
Flow control: none
Transmit delay
0 msec/char
0 msec/line

Fig.4: to communicate with the *Micromite LCD BackPack's* console, the terminal emulator must be set to 38,400 baud, 8 bits data, no parity and one stop bit. This example shows the serial set-up dialog box for Tera Term.



```
Micromite MKII MMBasic Ver 5.1
Copyright 2011-2015 Geoff Graham

> 
```

Fig.5: when you connect the *Micromite LCD BackPack* to a PC and press the reset button on the *BackPack*, you should see the start-up banner displayed as shown here. The terminal emulator used here is Tera Term.

POWER
ACTIVE
STATUS
PICkit™ 3
MICROCHIP

of chip that you are programming (PIC32MX170F256B), load the firmware (the HEX file) and click on the 'Program' button. The PICkit 3 will then program and verify the chip in less than a minute.

the RUN command, which will cause the Micromite to start running it.

If an error occurs, the Micromite will print an error message on the console and return to the command prompt. This is where the in-built editor is particularly useful. You can enter the command EDIT and the editor will place the cursor on the line that caused the error. When you have fixed the fault, you press F2 which will instruct the editor to save the program and run it again. This edit/run cycle is very fast and helps make programming the Micromite a breeze.

Configuring the LCD panel

The first thing that you need to do when you have the *Micromite LCD BackPack* running and connected to the console is configure it for the LCD. To do this, type the following line at the command prompt and hit the Enter key:

```
OPTION LCDPANEL ILI9341, L,
2, 23, 6
```

This tells the Micromite that the LCD panel is connected and what I/O pins are used for critical signals such as reset and device select. This option only needs to be entered once because the Micromite will store the setting in its internal non-volatile memory and will automatically reapply it whenever power is applied.

After this command, the Micromite initialises the display (it should go dark) and return to the command prompt. You can test the display by entering the following at the command prompt:

```
GUI TEST LCDPANEL
```

This will cause the Micromite to draw a series of rapidly overlapping coloured circles on the display. This animated test will continue until you press any key on the console's keyboard and MMBasic will then return to the command prompt.

To configure the touch feature you should enter the following at the command prompt:

```
OPTION TOUCH 7, 15
```

This command allocates the I/O pins for the touch controller and initialises

This photo shows the display when the command `GUI TEST LCDPANEL` is used. It is animated, with random circles being rapidly drawn on top of each other and makes a good test of the Micromite and LCD combination.

Parts List

- 1 PCB, available from the *EPE PCB Service*, coded 07102121, 77 × 45mm for 2.4-inch LCD; or code 07102122, 86 × 50mm for 2.8-inch LCD
- 1 ILI9341-based LCD, 320 × 240 pixels, 2.2-inch, 2.4-inch or 2.8-inch diagonal
- 1 4-pin tactile switch, through-hole
- 1 100Ω vertical mounting side-adjust trimpot)
- 1 28-pin DIL low-profile IC socket
- 1 4-pin 0.1-inch male header (CON1)
- 1 18-pin 0.1-inch male header (CON2)
- 1 14-pin 0.1-inch female header socket (CON3)
- 1 6-pin 0.1-inch right-angle male header (CON4)
- 4 M3 × 12mm tapped spacers
- 8 M3 × 6mm machine screws OR
- 4 M3 × 16mm machine screws and matching nuts

Semiconductors

- 1 PIC32MX170F256B-50I/SP microcontroller programmed with Micromite Mk2 firmware, V5.1 or later (IC1). Note: a PIC32MX170F256B-I/SP can also be used but will be limited to 40MHz
- 1 Microchip MCP1700-3302E/TO voltage regulator (IC2)

Capacitors

- 1 47µF 16V tantalum or SMD ceramic (3216/1206)
- 2 10µF 16V tantalum or SMD ceramic (3216/1206)
- 2 100nF monolithic ceramic

Resistors (1%, 0.25W)

- 1 10kΩ

Where to buy parts

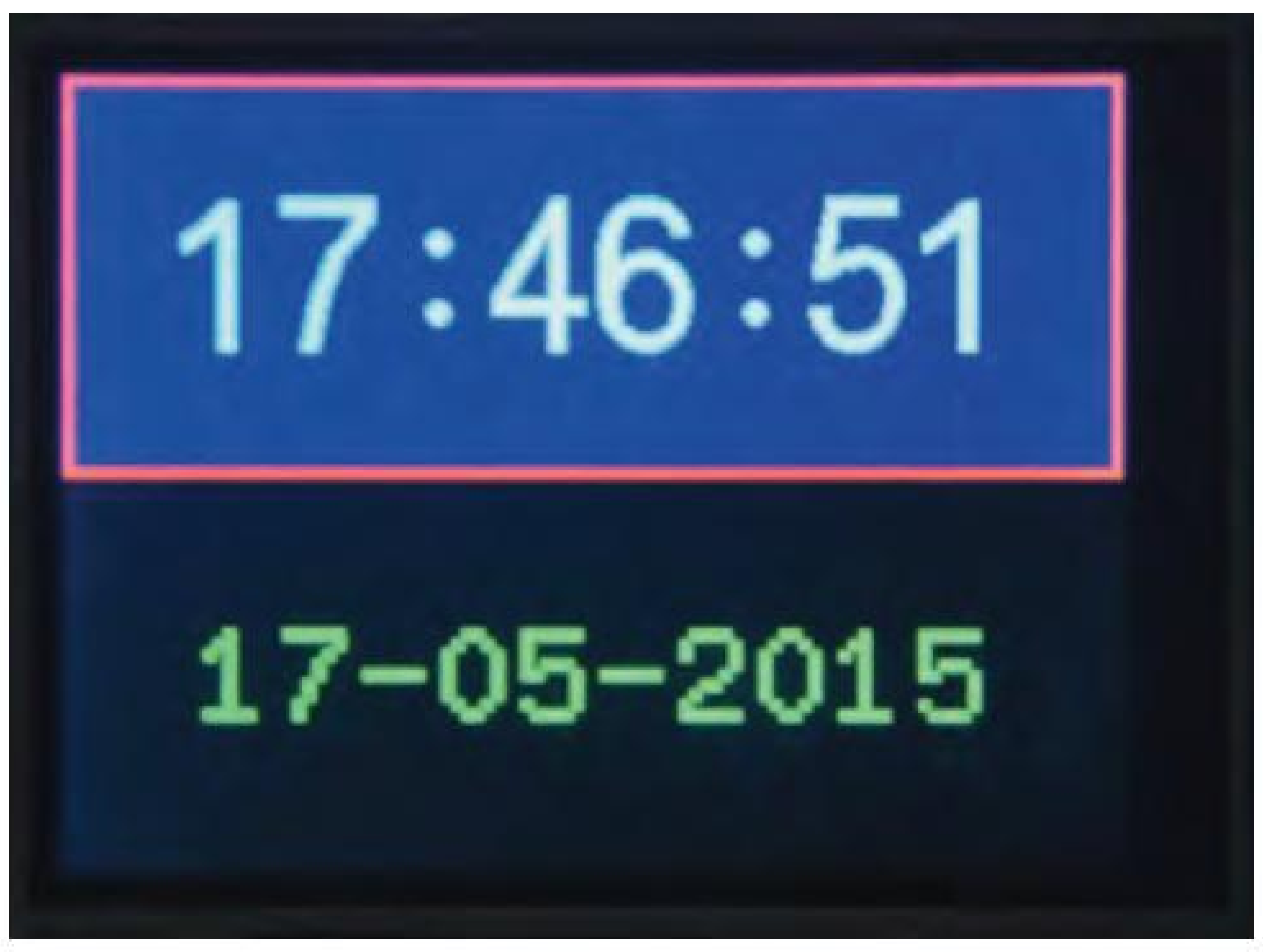
A complete kit for the *Micromite LCD BackPack* will be available from the Silicon Chip Online Shop. This includes a 2.8-inch TFT touchscreen and matching PCB, plus the programmed microcontroller and all other parts as listed above.

The PCBs, the pre-programmed PIC32MX170F256B-50I/SP microcontroller and the MCP1700-3302E/TO voltage regulator can also be purchased separately from the Online Shop.

```
CLS
BOX 0, 0, MM.HRes-1, MM.VRes/2, 3, RGB(RED), RGB(BLUE)

DO
  TEXT MM.HRes/2, MM.VRes/4, TIME$, CM, 1, 4, RGB(CYAN), RGB(BLUE)
  TEXT MM.HRes/2, MM.VRes*3/4, DATE$, CM, 1, 3, RGB(GREEN)
  IF TOUCH(X) <> -1 THEN END
LOOP
```

Fig.6: this simple program will display a clock/calendar on the LCD panel.



This is the result of running the test program for a simple clock described in the text. Note that the font used in the photo is different from the font that you will see.

it. This option is also stored in non-volatile memory and is automatically applied on power-up.

You do not have to run this command if your panel does not have a touch-sensitive screen, but you must use it if your LCD does have a touch facility – even if you will not be using touch in your program. This is because the touch chip select line could 'float', causing the touch controller to respond to commands intended for the panel's ILI9341 controller

With the touch feature configured, MMBasic will know to keep the touch chip select line inactive. Before you can use the touch facility you need to calibrate it. This is done with the following command:

```
GUI CALIBRATE
```

This will cause MMBasic to draw a target at the top lefthand corner of the screen as shown in the photo. Next, using a pointy but blunt object, press on the exact centre of the target. After a second, the target will disappear and when you lift your touch another target will appear on the top right.

By repeating the above procedure, the target will be displayed, in turn, on all four corners of the display and the touch feature will be calibrated. When completed, the message 'Done. No errors' should be displayed on the console. You also might get a message indicating that the calibration was inaccurate and in that case you should repeat it, taking more care to apply a steady press on the centre of the target.

As before, these calibration details are saved in non-volatile memory and will be reapplied at power up. You can now test the touch facility with the command:

```
GUI TEST TOUCH
```

This will clear the screen and when you touch it, pixels will be illuminated at the touch point. This enables you to test the accuracy of the calibration. Using a stylus, touch the screen and the pixels under the touch point should light. Pressing any key will terminate the test. You can also use this test feature as a simple drawing screen, rather like a high-tech version of an 'Etch A Sketch'.

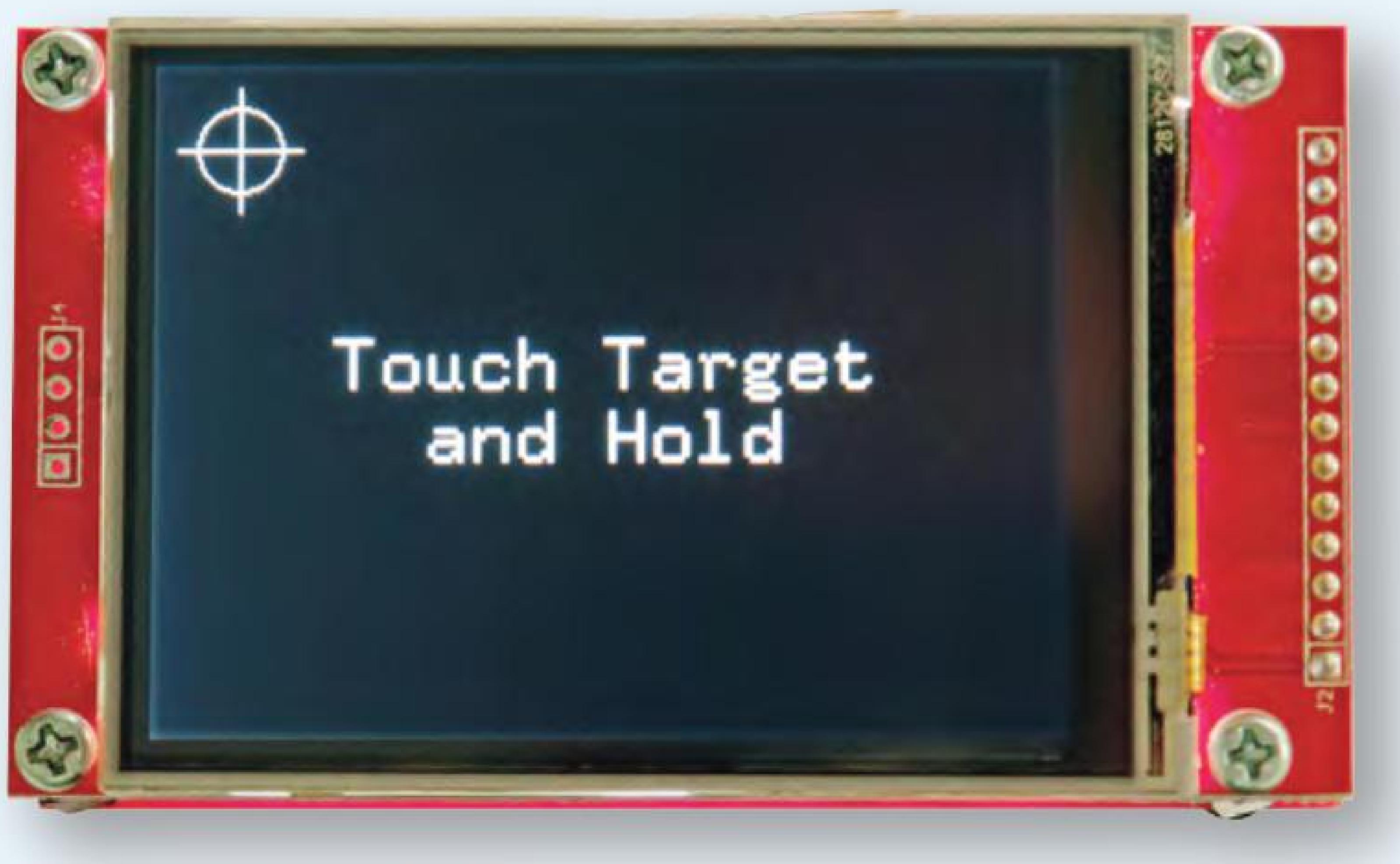
Fault-finding

Because it's so simple, there's not a lot that can go wrong with the *Micromite LCD BackPack*. If the display doesn't light or perform as it should, the first thing to do is check that the correct supply voltages are on IC1's socket and on CON3 (the LCD connector).

That done, check the 5V supply current for the full module, including the LCD. It should range from 100-200mA, depending on the setting of the backlight trimpot. If it is substantially lower than this, check that the PIC32 and the LCD are correctly seated in their sockets.

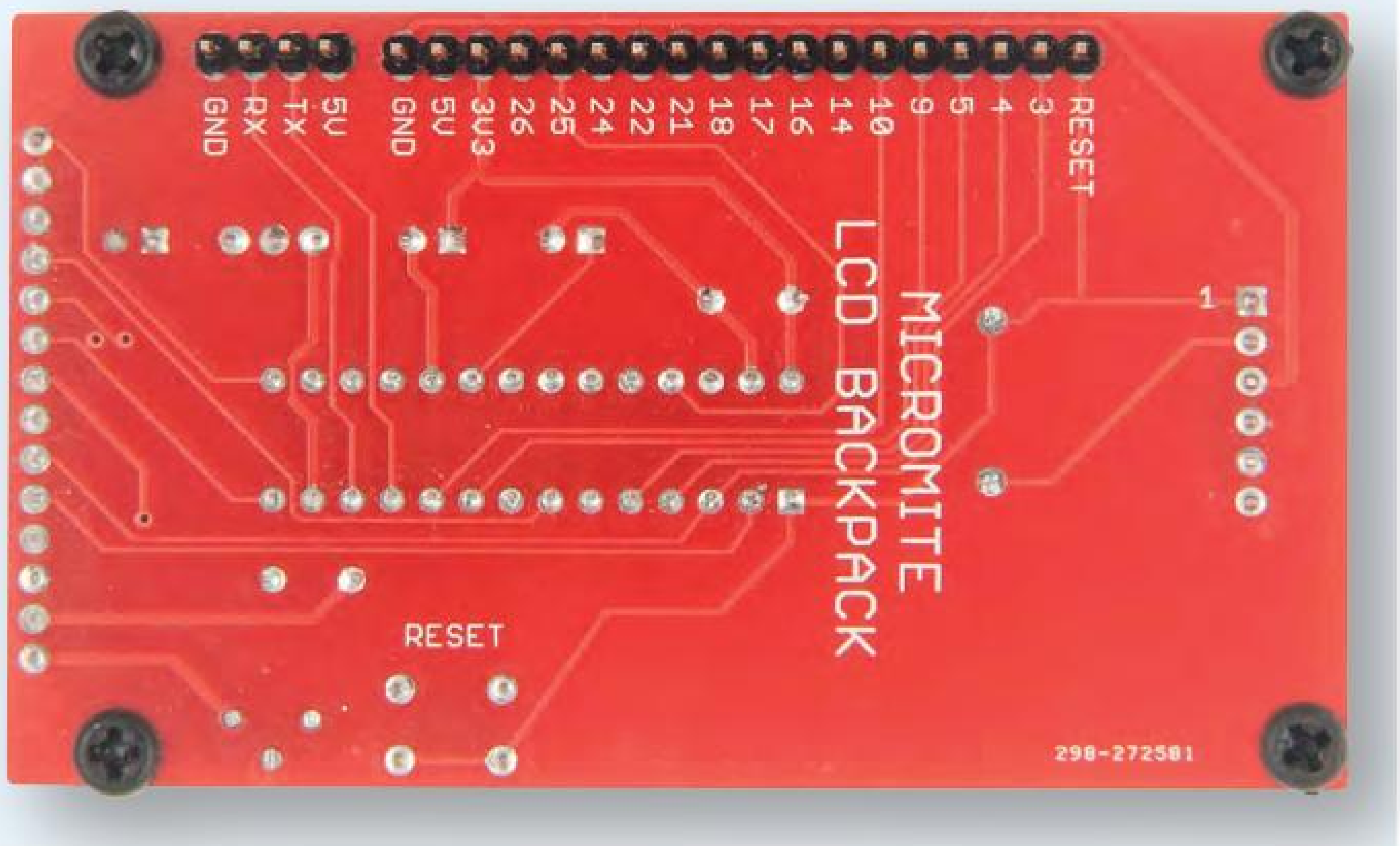
With the LCD removed, the power consumption should be about 25mA. If it is a lot less than this, it indicates that the PIC32 processor has not started up and in that case the 47µF capacitor is the most likely culprit. As previously stated, it must be a tantalum or multilayer ceramic type, not an electrolytic.

If the voltages and power consumption are correct, the problem could be with the console connection. Disconnect the USB-to-serial converter and join its TX and RX pins. Then try typing something into the terminal



This is an example of the display when calibrating the touch screen using the command GUI CALIBRATE.

Example of the display when the command GUI TEST TOUCH is used. It illuminates pixels where touched and is a good test for the touch calibration.



The rear side of the Micromite BackPack PCB is silk-screened with the functions and pin numbers of the console and I/O connectors. This makes it easy to identify the correct connector pin when the Micromite BackPack PCB and the LCD panel are fastened together.

Firmware updates

For firmware updates and manual please check the author's website at: **geoffg.net/micromite.html**

You should also check out the Back Shed forum (**www.thebackshed.com/forum/Microcontrollers**) where there are many Micromite enthusiasts who are happy to help beginners.

emulator. You should see your characters echoed back and if that doesn't happen, it indicates a fault with the converter or the terminal emulator.

If the USB-serial converter checks out, the fault could be related to the console connection to the *Micromite LCD BackPack*. Make sure that TX connects to RX and vice versa, and that the baud rate is 38,400. If you have an oscilloscope, you should be able to see a burst of activity on the *BackPack's* TX line on power up. This is the Micromite sending its start-up banner.

Test program

With the *Micromite LCD BackPack* working, you are ready to enter a test program. Using any of the three methods mentioned before (`EDIT`, `AUTOSAVE` or `XMODEM`), enter the sample program shown in Fig.6.

This program will display a simple clock/calendar on the LCD panel as shown in an accompanying photo (note that the font used in the photo is different from the font that you will see). Touching the screen will terminate the program.

The program starts by drawing a box with red walls and a blue interior. It then enters a continuous loop where it performs three functions:

1) It displays the current time inside the previously drawn box. The string is drawn centred both horizontally and vertically in the middle of the box
2) It draws the date centred in the lower half of the screen
3) It checks for a touch on the screen. This is indicated when the `TOUCH(X)` function returns something other than -1. In that case, the program will terminate.

Interfacing

The *Micromite LCD Backpack* interfaces to the 'outside world' via CON2, the main I/O connector. This is designed so that you can plug it into a solderless breadboard or connect to a third board mounted on the back on the *BackPack*.

The silk-screen on the PCB identifies each pin on the connector. The GND, 5V and 3.3V pins can be used to power your external interface circuitry. The maximum current that can be drawn from the 3.3V pin is 150mA, while the maximum 5V load will depend on your 5V supply. The RESET pin is normally pulled up by the onboard 10kΩ resistor to +3.3V and if you pull it low, the Micromite will reset.

The other I/O pins connect directly to the Micromite and are marked with the Micromite's pin number. Refer to the *Micromite User Manual* for details of what you can do with each pin.

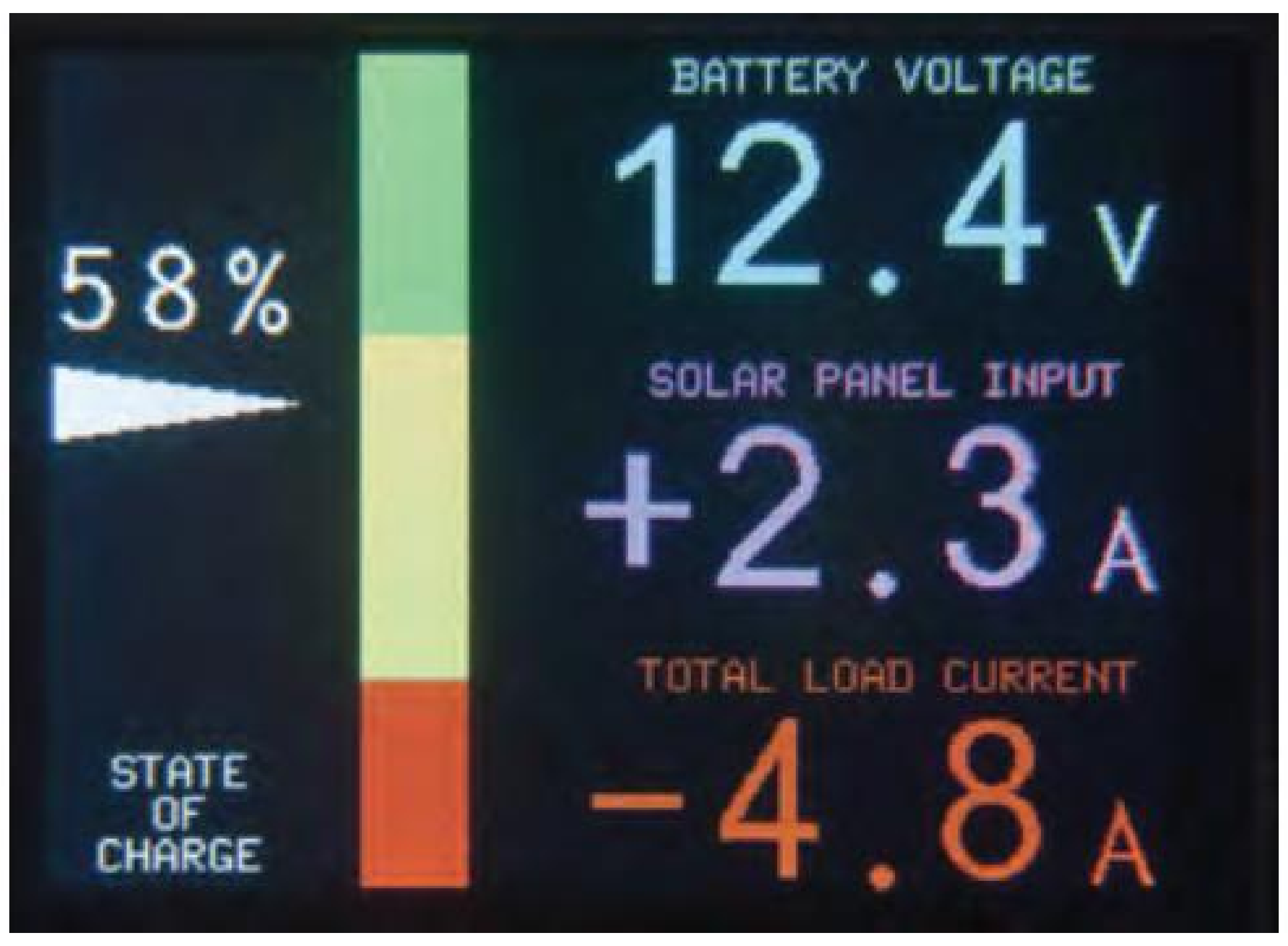
As an example, you could configure one of the analogue-capable pins (say pin 4) to measure voltage. The command to do this is:

```
SETPIN 4, AIN
```

Measuring the voltage on that pin is then as simple as using the `PIN()` function. For example:

```
PRINT PIN(4)
```

This will display the voltage at pin 4 on the console.



A test program for a lead-acid battery state of charge monitor using the *Micromite LCD BackPack*. The bar on the left shows the state of charge while the numbers on the right display the battery voltage, charging current in amps (from a solar panel) and the discharge current.

EGT
-16
CHT
-16
OIL
-16
AMP
-13
OAT
-10
VOLT
-16

A test program for an engine monitor using the *Micromite LCD BackPack*. The display updates smoothly, with the needles reacting very quickly to any change. Program courtesy Peter Mather on the Back Shed Forum.

Three of the pins on CON2 (pins 3, 14 and 25) are also connected to the colour LCD for communicating with the display using the SPI protocol. For this reason, they cannot be used as general-purpose I/O pins. However, they can still be used for SPI communications if needed; this is why they are included on this connector.

The *Micromite User Manual* describes how to use the SPI interface simultaneously with the LCD and it's not hard to do. However, for normal operation, you should just make sure that you do not use pins 3, 14 and 25 for general I/O.

Well, that's it – an inexpensive processor and display package with a host of possibilities. What plans do you have for it?

Reproduced by arrangement
with SILICON CHIP
magazine 2017.
www.siliconchip.com.au

EXCLUSIVE OFFER

Win a Microchip Curiosity PIC32MZ EF Development Board

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip Curiosity PIC32MZ EF Development Board (DM320104).

The Curiosity PIC32 MZ EF Development Board is a fully integrated 32-bit development platform featuring the high performance PIC32MZ EF Series (PIC32MZ2048EFM) that includes a 2MB of Flash, memory 512KB RAM, integrated FPU, Crypto accelerator and excellent connectivity options.

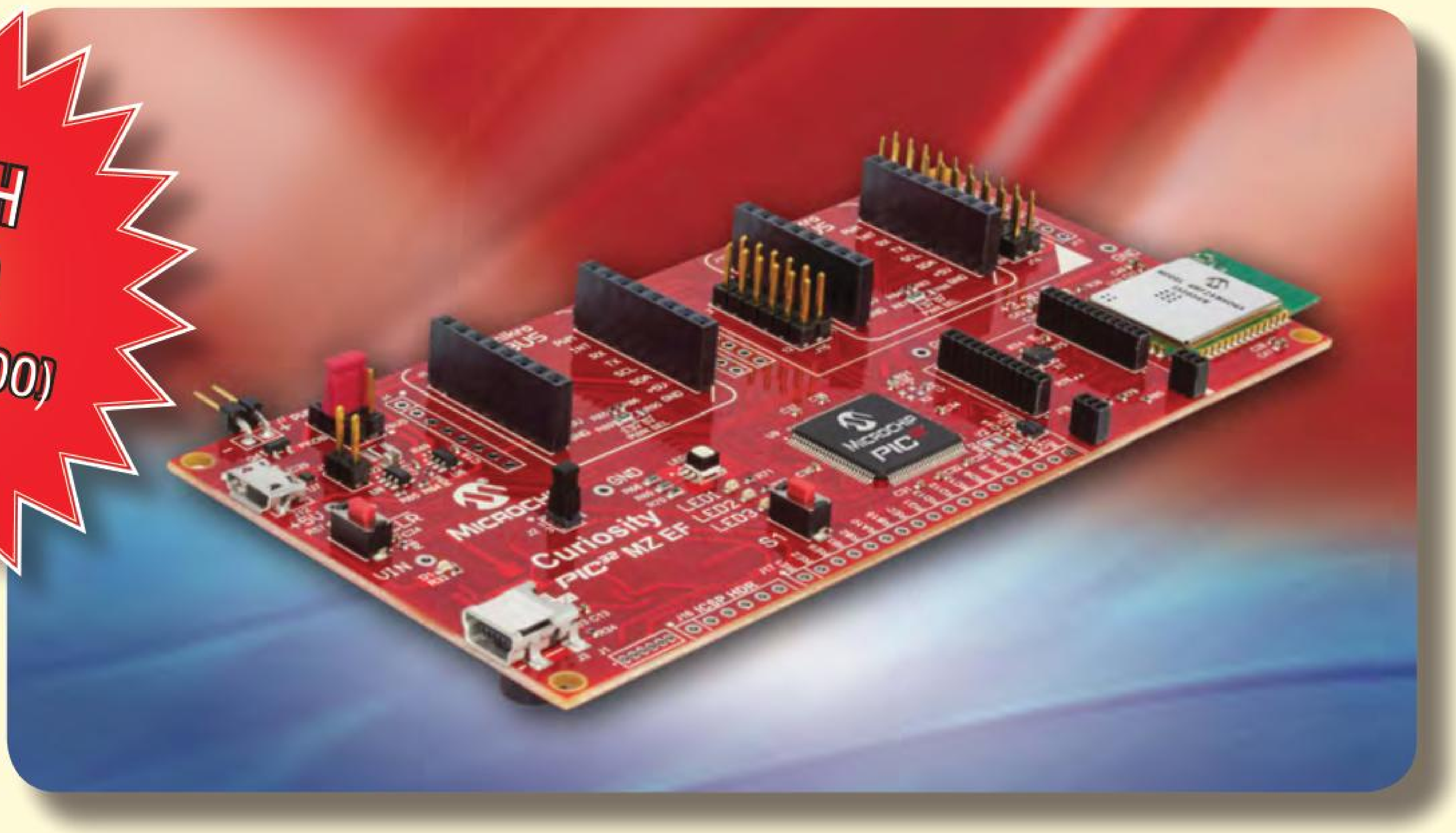
The Curiosity Development Board includes an integrated programmer/debugger, an on-board Wi-Fi-N module (MRF24WN0MA-I/RM100) and is fully integrated with Microchip's MPLAB X IDE.

Each board provides two MikroBus expansion sockets from MicroElektronika and a Microchip X32 header to support customers seeking accelerated application prototype development. Boards are fully integrated into PIC32's powerful software framework, MPLAB Harmony, that provides a flexible and modular interface to application development, a rich set of inter-operable software stacks (TCP-IP, USB) and easy-to-use features.

The boards and ecosystem have been designed to provide an excellent out-of-the-box experience. Designers are able to download and run example applications/projects instantly on the boards without the need to install the entire ecosystem. The demos have been developed to showcase PIC32 MCU features and the application development ecosystem.

The board offers expansion capabilities, making it an excellent choice for a rapid prototyping board for connectivity, IoT and general-purpose applications.

WORTH
$47.99
(approx. £40.00)
EACH



HOW TO ENTER

For your chance to win a Microchip Curiosity PIC32MZ EF Development Board, visit: **www.microchip-comps.com/epe-pic32mz** and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 31 May 2017.

January 2017 ISSUE WINNER

Mr Ian Williams, who works at Sterling Security Systems Ltd, Staffordshire, UK

He won a Microchip TimeFlash Oscillator Programming Kit with Socket Cards, valued at £160.00

HP 34401A Digital
Multimeter 6 ½ Digit

HP 54600B Oscilloscope Analogue/Digital
Dual Trace 100MHZ

MARCONI 2955B Radio
Communications Test Set

FLUKE/PHILIPS PM3092 Oscilloscope
2+2 Channel 200MHZ Delay TB, Autoset etc

LAMBDA GENESYS	PSU GEN100-15 100V 15A Boxed As New	£325
LAMBDA GENESYS	PSU GEN50-30 50V 30A	£325
HP34401A	Digital Multimeter 6.5 digit	£275-£325
HP33120A	Function Generator 100 microHZ-15MHZ	£260-£300
HP53131A	Universal Counter 3GHZ Boxed unused	£500
HP53131A	Universal Counter 225MHZ	£350
HP54600B	Digital Oscilloscope 100MHZ 20MS/S	from £75
IFR 2025	Signal Generator 9kHz - 2.51GHZ Opt 04/11	£900
Marconi 2955B	Radio Communications Test Set	£800
R&S APN62	Syn Function Generator 1HZ-260KHZ	£195
Fluke/Philips PM3092	Oscilloscope 2+2 Channel 200MHZ Delay etc	£250
HP3325A	Synthesised Function Generator	£195
HP3561A	Dynamic Signal Analyser	£650
HP6032A	PSU 0-60V 0-50A 1000W	£750
HP6622A	PSU 0-20V 4A Twice or 0-50V 2A Twice	£350
HP6624A	PSU 4 Outputs	£350
HP6632B	PSU 0-20V 0-5A	£195
HP6644A	PSU 0-60V 3.5A	£400
HP6654A	PSU 0-60V 0-9A	£500
HP8341A	Synthesised Sweep Generator 10MHZ-20GHZ	£2,000
HP83731A	Synthesised Signal Generator 1-20GHZ	£1,800
HP8484A	Power Sensor 0.01-18GHZ 3nW-10uW	£75
HP8560A	Spectrum Analyser Synthesised 50HZ - 2.9GHZ	£1,250
HP8560E	Spectrum Analyser Synthesised 30HZ - 2.9GHZ	£1,750
HP8563A	Spectrum Analyser Synthesised 9KHZ-22GHZ	£2,250
HP8566B	Spectrum Analsyer 100HZ-22GHZ	£1,200
HP8662A	RF Generator 10KHZ - 1280MHZ	£750
Marconi 2022E	Synthesised AM/FM Signal Generator 10KHZ-1.01GHZ	£325
Marconi 2024	Synthesised Signal Generator 9KHZ-2.4GHZ	£800
Marconi 2030	Synthesised Signal Generator 10KHZ-1.35GHZ	£750
Marconi 2305	Modulation Meter	£250
Marconi 2440	Counter 20GHZ	£295
Marconi 2945	Communications Test Set Various Options	£2,500
Marconi 2955	Radio Communications Test Set	£595
Marconi 2955A	Radio Communications Test Set	£725
Marconi 6200	Microwave Test Set	£1,500
Marconi 6200A	Microwave Test Set 10MHZ-20GHZ	£1,950
Marconi 6200B	Microwave Test Set	£2,300
Marconi 6960B with	6910 Power Meter	£295

Tektronix TDS3012	Oscilloscope 2 Channel 100MHZ 1.25GS/S	£450
Tektronix 2430A	Oscilloscope Dual Trace 150MHZ 100MS/S	£350
Tektronix 2465B	Oscilloscope 4 Channel 400MHZ	£600
Cirrus CL254	Sound Level Meter with Calibrator	£40
Farnell AP60/50	PSU 0-60V 0-50A 1KW Switch Mode	£195
Farnell H60/50	PSU 0-60V 0-50A	£500
Farnell B30/10	PSU 30V 10A Variable No Meters	£45
Farnell B30/20	PSU 30V 20A Variable No Meters	£75
Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
Farnell LF1	Sine/sq Oscillator 10HZ-1MHZ	£45
Racal 1991	Counter/Timer 160MHZ 9 Digit	£150
Racal 2101	Counter 20GHZ LED	£295
Racal 9300	True RMS Millivoltmeter 5HZ-20MHZ etc	£45
Racal 9300B	As 9300	£75
Black Star Orion	Colour Bar Generator RGB & Video	£30
Black Star 1325	Counter Timer 1.3GHZ	£60
Ferrograph RTS2	Test Set	£50
Fluke 97	Scopemeter 2 Channel 50MHZ 25MS/S	£75
Fluke 99B	Scopemeter 2 Channel 100MHZ 5GS/S	£125
Gigatronics 7100	Synthesised Signal Generator 10MHZ-20GHZ	£1,950
Panasonic VP7705A	Wow & Flutter Meter	£60
Panasonic VP8401B	TV Signal Generator Multi Outputs	£75
Pendulum CNT90	Timer Counter Analyser 20GHZ	£750
Seaward Nova	PAT Tester	£95
Solartron 7150	6 1/2 Digit DMM True RMS IEEE	£65
Solartron 7150 Plus	as 7150 plus Temp Measurement	£75
Solatron 7075	DMM 7 1/2 Digit	£60
Solatron 1253	Gain Phase Analyser 1mHZ-20KHZ	£600
Tasakago TM035-2	PSU 0-35V 0-2A 2 Meters	£30
Thurlby PL320QMD	PSU 0-30V 0-2A Twice	£160-£200
Thurlby TG210	Function Generator 0.002-2MHZ TTL etc Kenwood Badged	£65

STEWART OF READING
17A King Street, Mortimer, near Reading, RG7 3RS
Telephone: **0118 933 1111** Fax: **0118 9331275**
USED ELECTRONIC TEST EQUIPMENT
Check website **www.stewart-of-reading.co.uk**

Check out our website: www.epemag.com

Laser *Why tolerate when you can automate?*

X-10 **Home Automation**

KAT5 AV transmission and IR control system

Barix Ethernet based MP3, communications and control systems

www.laser.com

Integrators, Installers, Trade and Retail customers welcome

C-Bus Shop

C-Bus and C-Bus Wireless

www.cbus-shop.com

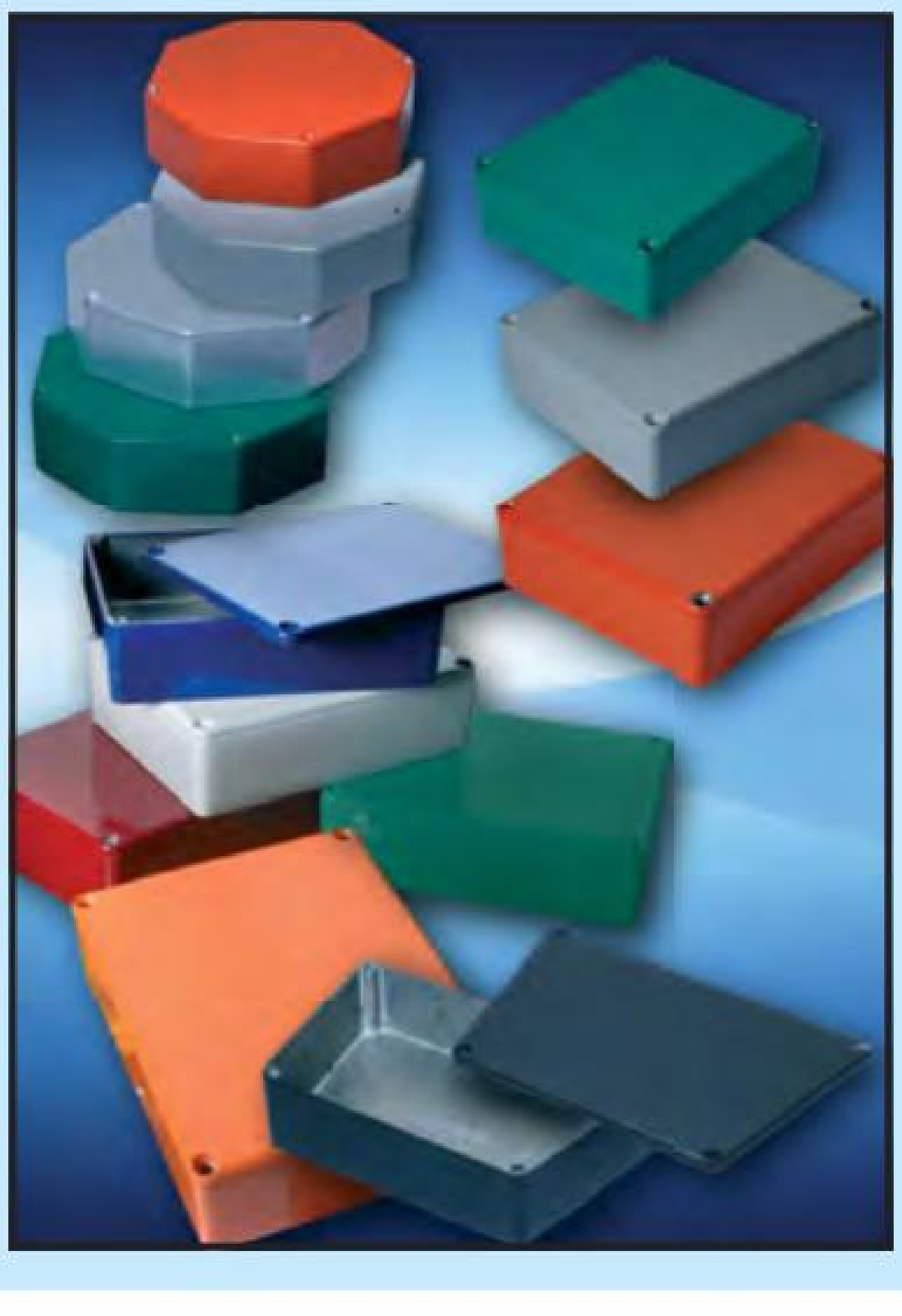
Laser Business Systems Ltd
Tel: +44 (0) 20 8441 9788
Fax: +44 (0) 20 8449 0430
Email: info@laser.com
16 Garthland Drive, EN5 3BB

HAMMOND MANUFACTURING®

Die-cast enclosures standard & painted

www.hammondmfg.com/dwg.htm
www.hammondmfg.com/ dwg_SBVer.htm

01256 812812
sales@hammondmfg.eu



POWER
USB LINK TO PC
2.50V DC
RF LEVEL & POWER
AUDIO LEVEL & POWER
200V DC
USB LINKED MULTIFUNCTION 24-BIT MEASURING SYSTEM
DC VOLTAGE INPUTS
+2.50V/25.0V
+250V/1000V
RF HEAD END
AUDIO INPUT
RF INPUT
RF MEASURING HEAD FOR MFM
INTERCEPT ADJUST
OUTPUT TO MFM

Part 2: By Jim Rowe

Arduino Multifunction 24-Bit Measuring Shield

Last month, we introduced our new *Arduino-based Multifunction Meter* (*MFM*) and gave the circuit details. This month, we describe how to install the software and firmware that's needed to control it from a desktop or laptop PC. We then explain how to get it going, how to calibrate the various ranges (if you have the facilities) and how to use the finished unit.

AS MENTIONED in Part 1, a couple of pieces of software need to be installed on your PC in order to use the *MFM*. In addition, a 'sketch' (Arduino-speak for firmware program) has to be uploaded into the Flash memory of the Arduino to enable it to carry out its tasks.

This is detailed in the software block diagram of Fig.7. The large box at left represents a PC (desktop or laptop) running Windows XP/SP3 or later (you're not still using Windows XP, are you?). The *MFM* is shown over on the right, linked to the PC via a USB cable.

The MFM Control and Display Application (upper left) needs to be installed on the PC, together with a virtual COM port driver (lower right in the PC box) to allow it to communicate with the Arduino in the sampler. The Arduino IDE (integrated development environment) also needs to be installed in your PC, at least temporarily, in order to upload the *MFM* sketch to the Arduino module. Here's the step-by-step procedure:

Step 1: download and install the Arduino IDE from the main Arduino website at **https://www.arduino.cc/en/Main/Software**. We used the **1.6.5-r2-windows.exe** version but there may be a later one by the time you read this. There's also a zipped-up version.

The Arduino IDE comes with a USB virtual COM port driver to suit the Arduino Uno, and this is installed in the 'Drivers' folder of the IDE installation. As a result, if you are using an Arduino Uno in your sampler, you'll already have its matching USB port driver.

Alternatively, if you're using a Freetronics Eleven, go to **www.freetronics.com.au** and download their USB driver. At the time of writing, this was in a zip file called **FreetronicsUSBDrivers_v2.2.zip**. Unzip this and make a note of where the files have been extracted.

Step 2: plug the cable from your *MFM* into one of your PC's USB ports. The *MFM's* power LED should immediately

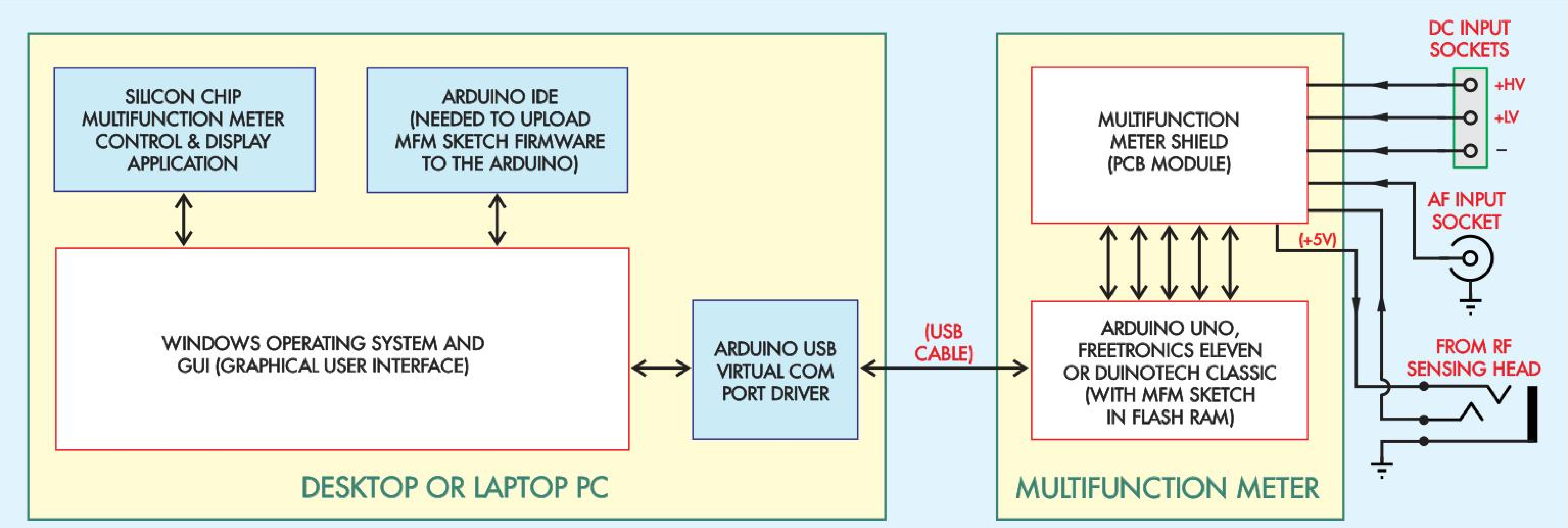

SILICON CHIP MULTIFUNCTION METER CONTROL & DISPLAY APPLICATION
ARDUINO IDE (NEEDED TO UPLOAD MFM SKETCH FIRMWARE TO THE ARDUINO)
WINDOWS OPERATING SYSTEM AND GUI (GRAPHICAL USER INTERFACE)
ARDUINO USB VIRTUAL COM PORT DRIVER
DESKTOP OR LAPTOP PC
(USB CABLE)
MULTIFUNCTION METER SHIELD (PCB MODULE)
ARDUINO UNO, FREETRONICS ELEVEN OR DUINOTECH CLASSIC (WITH MFM SKETCH IN FLASH RAM)
MULTIFUNCTION METER
(+5V)
DC INPUT SOCKETS
+HV
+LV
–
AF INPUT SOCKET
FROM RF SENSING HEAD

Fig.7: the software block diagram for the *MFM* system. The *MFM* connects to a Windows PC via a USB cable and is controlled by an application (app) running on the PC. The Arduino IDE software is required to upload the *MFM* 'sketch' firmware to the Arduino module in the *MFM*.

turn on but Windows may not successfully install the driver right away.

Step 3: open up the Windows Device Manager. If you see a yellow error icon alongside an 'Unknown device' listing, the driver has not installed automatically. Right-click the device and select Properties, it will be shown as either not working properly or not installed.

To fix this, select 'Update Driver' in the Properties dialog and then 'Browse my Computer for Driver Software'. Then browse to either the Drivers folder of your Arduino IDE installation (to get Arduino's Uno driver) or, alternatively, to the folder where you unzipped the Freetronics driver software.

In either case, you should be able to find the **.inf** file that Windows needs to install the driver. Once it's installed, the Device Manager should then indicate that the device is working properly.

Step 4: go to the *EPE* website and download both the Windows software for the MFM Control and Display App (**SiliconChipMFM.zip**) and the matching Arduino firmware sketch (**ArduinoMFMSketch.ino**).

The firmware sketch should be saved in a sub-folder called 'Arduino sketches' in your PC's Documents folder. That done, launch the Arduino IDE, direct it to that folder to find the sketch, open it, compile it and then upload it to the flash RAM in your MFM's Arduino. You will find that this is all quite straightforward.

Step 5: next, unzip the **SiliconChipMFM.zip** file to get the install package (**SiliconChipMFM.msi**), then run it to install the 'Windows MFM Control and Display' application. You should then be ready to roll with your new *24-bit MultiFunction Meter*.

Using the Windows app

Apart from the range selection (done via rotary switch S1), all functions on the *MFM* are controlled using the MFM Control and Display application. This is easy to use because when you fire it up, a GUI (graphical user interface) window appears (see Fig.8) which provides combo-boxes along the top so you can set the configuration of the *MFM*-PC serial link; ie, the (virtual) COM port to which it's connected and the baud rate (115,200).

There's also a third combo-box which allows you to select the external load resistance you will be using, if you intend using either the AF or RF level and power ranges. However, you don't have to worry about doing this if you simply intend measuring DC voltages.

Just below this top row of combo boxes is a box labelled 'Sampling interval:'. This allows you to select the sampling rate to be used when taking continuous or repetitive samples. You can choose from 13 different sampling intervals, ranging from 200ms (five samples per second) to 60s (one sample per minute).

Immediately to the right is a small check box with the label 'Live reading'. Clicking on this check box allows you to view *MFM* measurements in real time, at the same rate as that selected for continuous sampling. When 'Live reading' is enabled, the measurements are displayed just to the right of the 'Live reading' label itself, with each successive reading replacing the previous one.

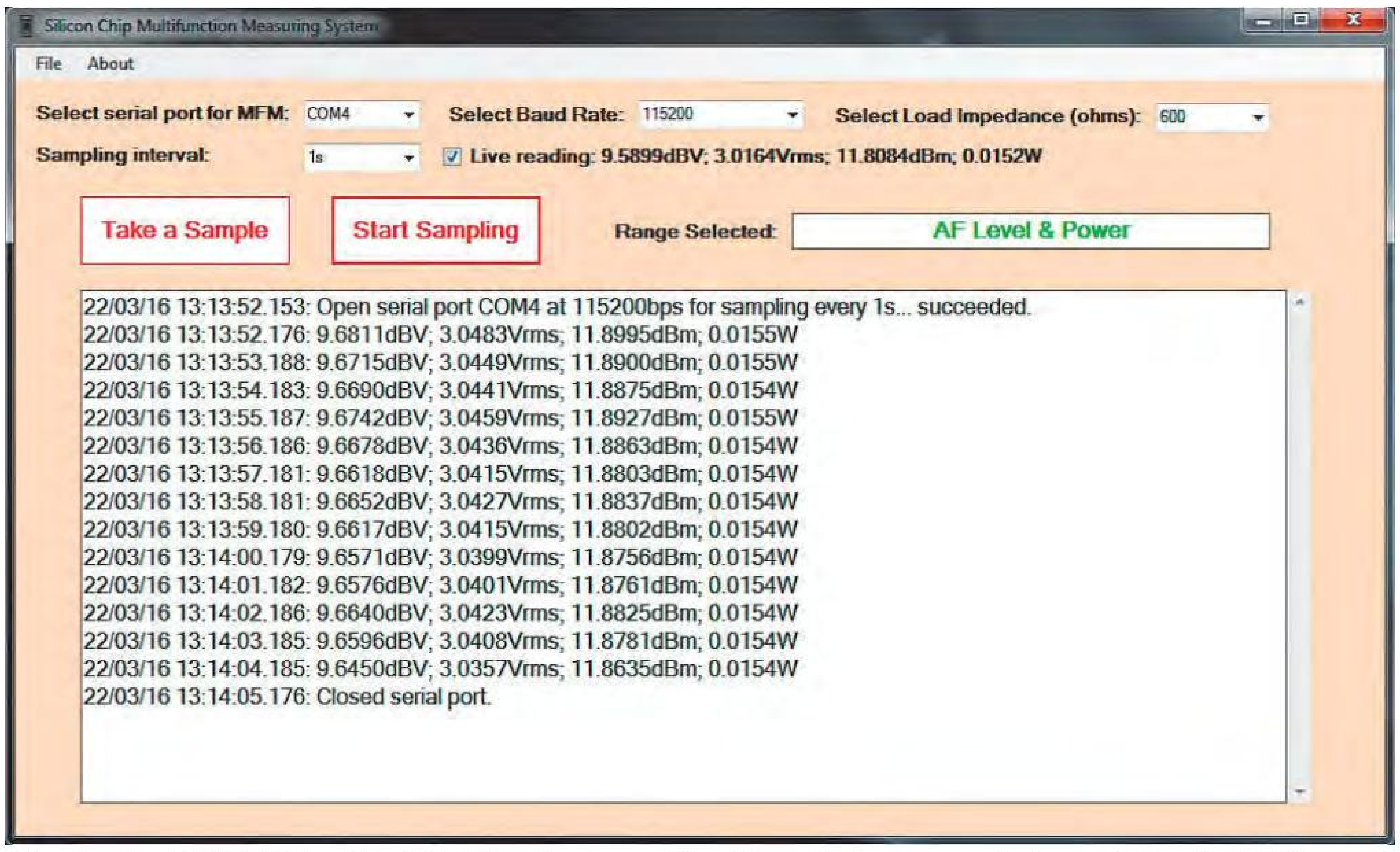
By the way, 'Live reading' may be enabled at the same time as continuous sampling, with the data for each measurement being displayed at top right as well as on the next available line in the main text box.

Further down the GUI window, you'll find two rectangular control buttons with red borders and red text labels reading 'Take a Sample' and 'Start Sampling' respectively. These allow you to either take a single measurement sample or to begin taking a series of samples at a rate corresponding to the selected sampling interval.

To the right of these two control buttons is a 'Range Selected:' label, followed by a text box which will initially be blank. However, when you begin taking measurement samples, this text box will show the *MFM* range that's been selected via range switch S1 on the *MFM* itself.

The lower portion of the GUI window is taken up by a text box which displays the measurement samples as they are made. Each sample is on a separate line and is preceded by the date and time at which it was taken.

In addition, when you first start sampling, the application displays a header line at the top showing not only the date and time, but also the virtual COM port and serial data rate being used, plus the sampling interval selected. This is to make the *MFM* and its control application more suited for measurement data logging.



Select serial port for MFM: COM4
Select Baud Rate: 115200
Select Load Impedance (ohms): 600
Sampling interval: 1s
☑ Live reading: 9.5899dBV; 3.0164Vrms; 11.8084dBm; 0.0152W
Range Selected: AF Level & Power

```
22/03/16 13:13:52.153: Open serial port COM4 at 115200bps for sampling every 1s... succeeded.
22/03/16 13:13:52.176: 9.6811dBV; 3.0483Vrms; 11.8995dBm; 0.0155W
22/03/16 13:13:53.188: 9.6715dBV; 3.0449Vrms; 11.8900dBm; 0.0155W
22/03/16 13:13:54.183: 9.6690dBV; 3.0441Vrms; 11.8875dBm; 0.0154W
22/03/16 13:13:55.187: 9.6742dBV; 3.0459Vrms; 11.8927dBm; 0.0155W
22/03/16 13:13:56.186: 9.6678dBV; 3.0436Vrms; 11.8863dBm; 0.0154W
22/03/16 13:13:57.181: 9.6618dBV; 3.0415Vrms; 11.8803dBm; 0.0154W
22/03/16 13:13:58.181: 9.6652dBV; 3.0427Vrms; 11.8837dBm; 0.0154W
22/03/16 13:13:59.180: 9.6617dBV; 3.0415Vrms; 11.8802dBm; 0.0154W
22/03/16 13:14:00.179: 9.6571dBV; 3.0399Vrms; 11.8756dBm; 0.0154W
22/03/16 13:14:01.182: 9.6576dBV; 3.0401Vrms; 11.8761dBm; 0.0154W
22/03/16 13:14:02.186: 9.6640dBV; 3.0423Vrms; 11.8825dBm; 0.0154W
22/03/16 13:14:03.185: 9.6596dBV; 3.0408Vrms; 11.8781dBm; 0.0154W
22/03/16 13:14:04.185: 9.6450dBV; 3.0357Vrms; 11.8635dBm; 0.0154W
22/03/16 13:14:05.176: Closed serial port.
```

Fig.8: the MFM Control & Display application lets you set the virtual COM port and baud rate for the *MFM*-PC serial link. It also allows you to select the load impedance and the sampling interval and to take either a single sample or a series of samples at the selected rate. The app is shown here displaying Vrms and dBm readings on the AF Level & Power range.

Making measurements

To take a measurement or a series of measurements, all you need to do is click on either the 'Take a Sample' button or the 'Start Sampling' button. The data then appears in the main textbox.

If you click the 'Start Sampling' button, the unit will continue to take further measurements at the selected time interval. During this time, the button label also changes to read 'Stop Sampling' and you can stop the sampling simply by clicking this button again.

So that's how simple it is to use our MFM Control and Display app for taking measurements. But what about saving the measurements? Easy – just click the 'File' drop-down menu at top left on the window and you'll see a number of handy options for saving, reopening or printing out your current collection of measurement samples.

There's also an option called 'New', for 'clearing the slate' before taking another set of samples, plus the usual option of closing the application itself at the end of the job. These all work the same way as for other Windows applications, so you shouldn't have any problems.

MFM set-up and calibration

There are no trimpots or other hardware items to adjust in order to calibrate the *MFM's* DC voltage ranges. That's because we're taking advantage of the accuracy built into the LTC2400 24-bit ADC, its companion LT1019ACS8 voltage reference and the 0.1% tolerance resistors used in the input dividers. These will give you an accuracy of ±0.06% (±1.25mV) on the basic 2.5V range and ±0.5% on the three higher ranges (ie, ±125mV on the 25V range, ±1.25V on the 250V range and ±5V on the 1000V range), without any adjustments.

However, if you happen to have access to a high-accuracy DC voltmeter, it can be used to measure the exact reference voltage being provided by the LT1019ACS8 voltage reference in the *MFM.* You can then make a single change in the *MFM* Arduino's firmware sketch to improve the accuracy of its basic 2.500V DC range (and of all the other ranges by default).

If you want to do this, first remove the control knob and the lid of the *MFM*, then plug its USB cable into your PC and use the high-accuracy DC voltmeter to measure the voltage from REF1, the LT1019ACS8. The easiest way to do this is to place your meter's test probes across ZD1, the 3.9V zener diode located just behind REF1.

Be sure to write the measured reference voltage down carefully, using as many significant digits as your voltmeter provides. The reading should be somewhere between 2.49875V and 2.50125V, because the LT1019ACS8-2.5 has an initial accuracy of ±0.05%.

Next, launch the Arduino IDE in your PC, open up the *MFM* firmware sketch (**ArduinoMFMSketch.ino**) and move down the sketch listing until you get to the start of the main loop; ie, a line which reads:

```
void loop() {
```

The next line should read:

```
const float Vref = 2.50000f;  //Vref = the ADC reference voltage
```

Replace '2.50000' in the above line with your own measured reference voltage, then use the Arduino IDE software to recompile the sketch and upload it to the Arduino in your *MFM.* This will make its 2.5V DC range and all of the other ranges as accurate as possible without access to a full-scale calibration lab.

Audio Level and Power range

Unlike the DC voltage ranges, the Audio Level and Power range does require some hardware set-up and adjustment.

To do this, you need an audio-frequency sinewave signal of at least 10VAC (RMS) and some way of accurately measuring its level. One possibility is to use an audio signal generator with an output meter and attenuator, or you could use an uncalibrated audio oscillator with a separate audio level meter to monitor its output.

Another possibility is to use an AC plugpack (ie, one with a conventional iron-core transformer) with a 9-24VAC secondary to provide the sinewave signal, together with an RMS-reading AC voltmeter (to measure the output voltage). If you use this latter approach, you'll be doing the set-up at 50Hz – but that's OK, since 50Hz is well inside the audio range.

On the other hand, if you are using an audio signal generator, it's probably a good idea to set its frequency to around 1kHz.

Once you have a suitable signal source, just follow this step-by-step procedure to set up and adjust the *MFM's* Audio Level and Power range:

Step 1: connect the *MFM* to your PC and check that it's operating normally.

Step 2: launch the MFM Control and Display app and set it up to communicate with the *MFM* via the previously installed virtual COM port at 115,200 baud.

Step 3: move the *MFM's* range switch to the fully anticlockwise 'Audio Level and Power' position, then fit a 50Ω termination plug to the Audio Input BNC connector (this will ensure a nominal input of near enough to zero).

Step 4: select a short sampling interval (eg, 200ms) and enable the Live Reading display. You'll probably initially see dBV/Vrms figures that are somewhat higher than they should be with the input terminated in just 50Ω.

Step 5: use a small screwdriver to adjust trimpot VR1 (Intercept Adjust) via the small hole in the case immediately to the left of the Audio Input BNC connector to achieve minimum readings. Ideally, you'll be able to get readings well below -47.5dBV and 4.2mV RMS.

Step 6: remove the 50Ω plug from the Audio Input connector and connect your audio signal source in its place.

Step 7: make small adjustments to trimpot VR2 (Slope Adjust) via the small hole just to the right of the Audio Input BNC connector. Make the Vrms reading as close as possible to the voltage of the input signal.

If you can't achieve the known Vrms reading, you may need to repeat Steps 3-5 to make further small adjustments to trimpot VR1. For example, if your reading in Step 7 remains stubbornly higher than the known input level, try reducing the 'zero input' reading by a small amount using VR1 before coming back to Step 7.

Conversely, if you are unable to increase the reading in Step 7 to reach the known input level, increase the 'zero input' reading by a small amount. It should then be possible to achieve the known input level reading by adjusting VR2.

Once the known input level reading has been achieved, the Audio Level and Power range has been correctly set up and calibrated. Note that its accuracy will depend on the accuracy of your audio signal generator's level meter (or the accuracy of your AC voltmeter).

By the way, we ignored readings other than dBV and Vrms in the previous steps because the other values are calculated from these (taking into account the selected load impedance). That means that it's only necessary to have the load impedance setting correct if you are actually making dBm and power readings.

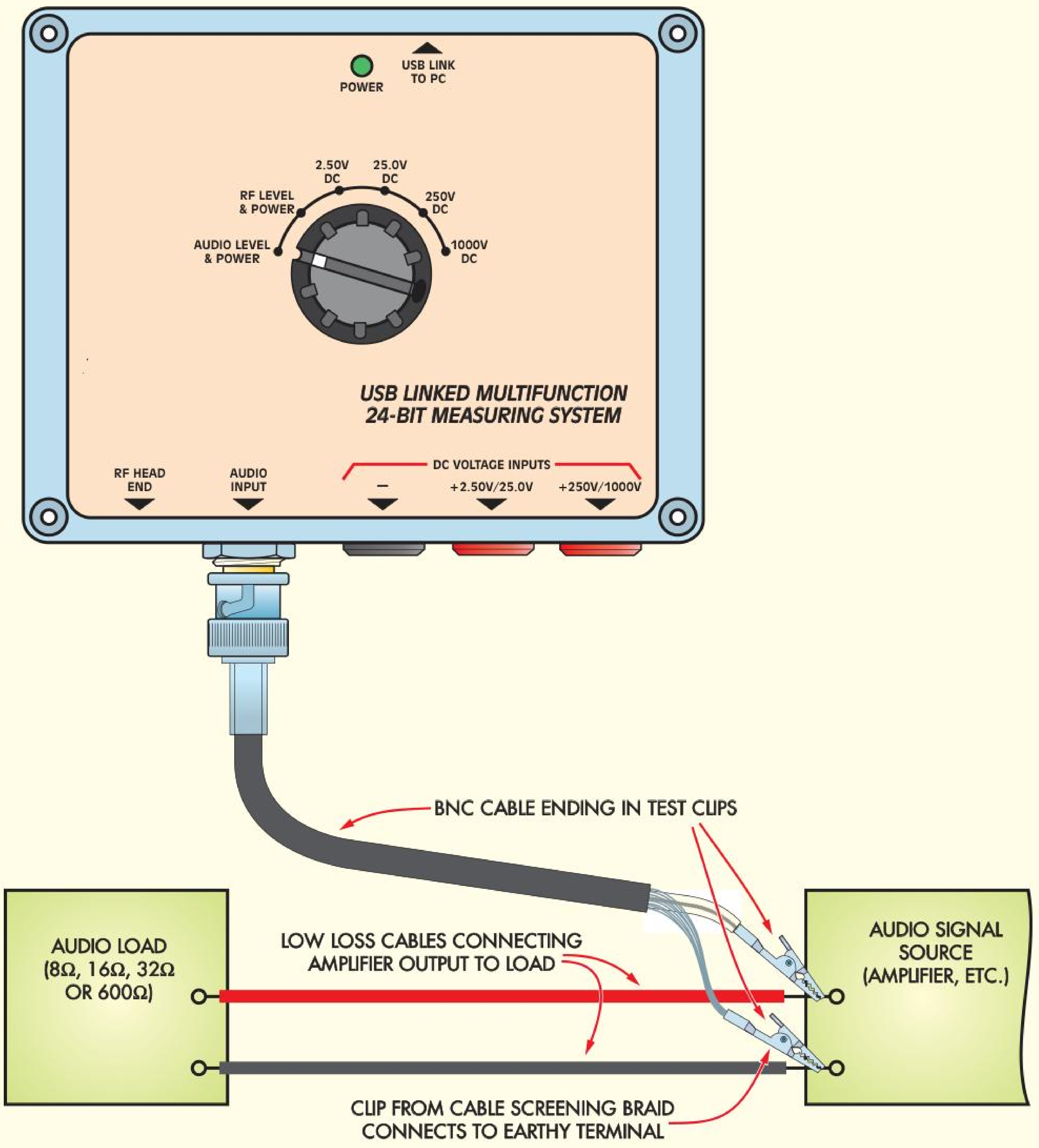

POWER
USB LINK TO PC
2.50V DC
25.0V DC
RF LEVEL & POWER
250V DC
AUDIO LEVEL & POWER
1000V DC
USB LINKED MULTIFUNCTION 24-BIT MEASURING SYSTEM
RF HEAD END
AUDIO INPUT
DC VOLTAGE INPUTS
–
+2.50V/25.0V
+250V/1000V
BNC CABLE ENDING IN TEST CLIPS
AUDIO LOAD (8Ω, 16Ω, 32Ω OR 600Ω)
LOW LOSS CABLES CONNECTING AMPLIFIER OUTPUT TO LOAD
AUDIO SIGNAL SOURCE (AMPLIFIER, ETC.)
CLIP FROM CABLE SCREENING BRAID CONNECTS TO EARTHY TERMINAL

Fig.9: the *MFM* can be used to measure power levels from an audio amplifier using the configuration shown here. Be sure to use low-loss cable to connect the load and be careful not to short the amplifier output terminals.

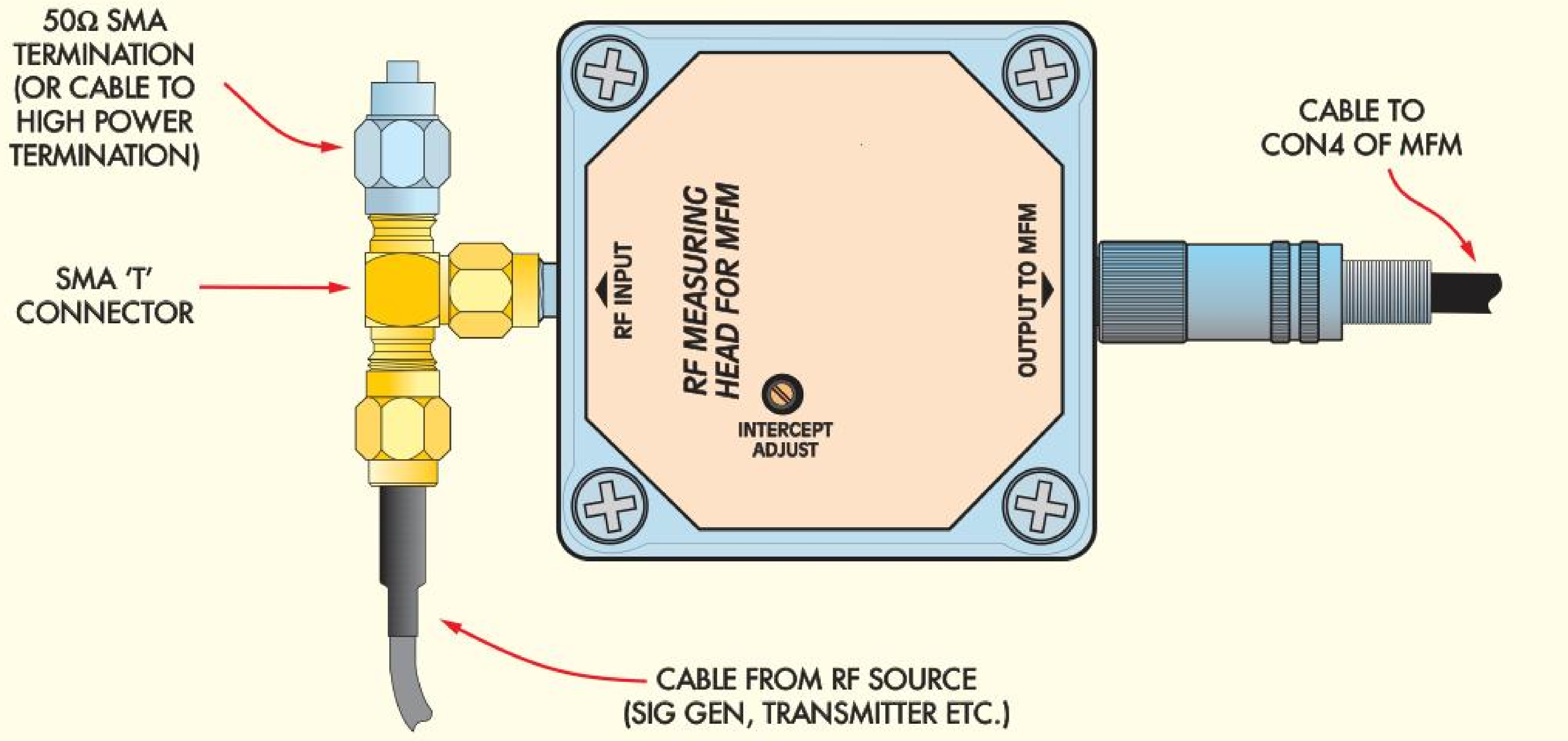

50Ω SMA TERMINATION (OR CABLE TO HIGH POWER TERMINATION)
SMA 'T' CONNECTOR
RF INPUT
RF MEASURING HEAD FOR MFM
OUTPUT TO MFM
INTERCEPT ADJUST
CABLE TO CON4 OF MFM
CABLE FROM RF SOURCE (SIG GEN, TRANSMITTER ETC.)

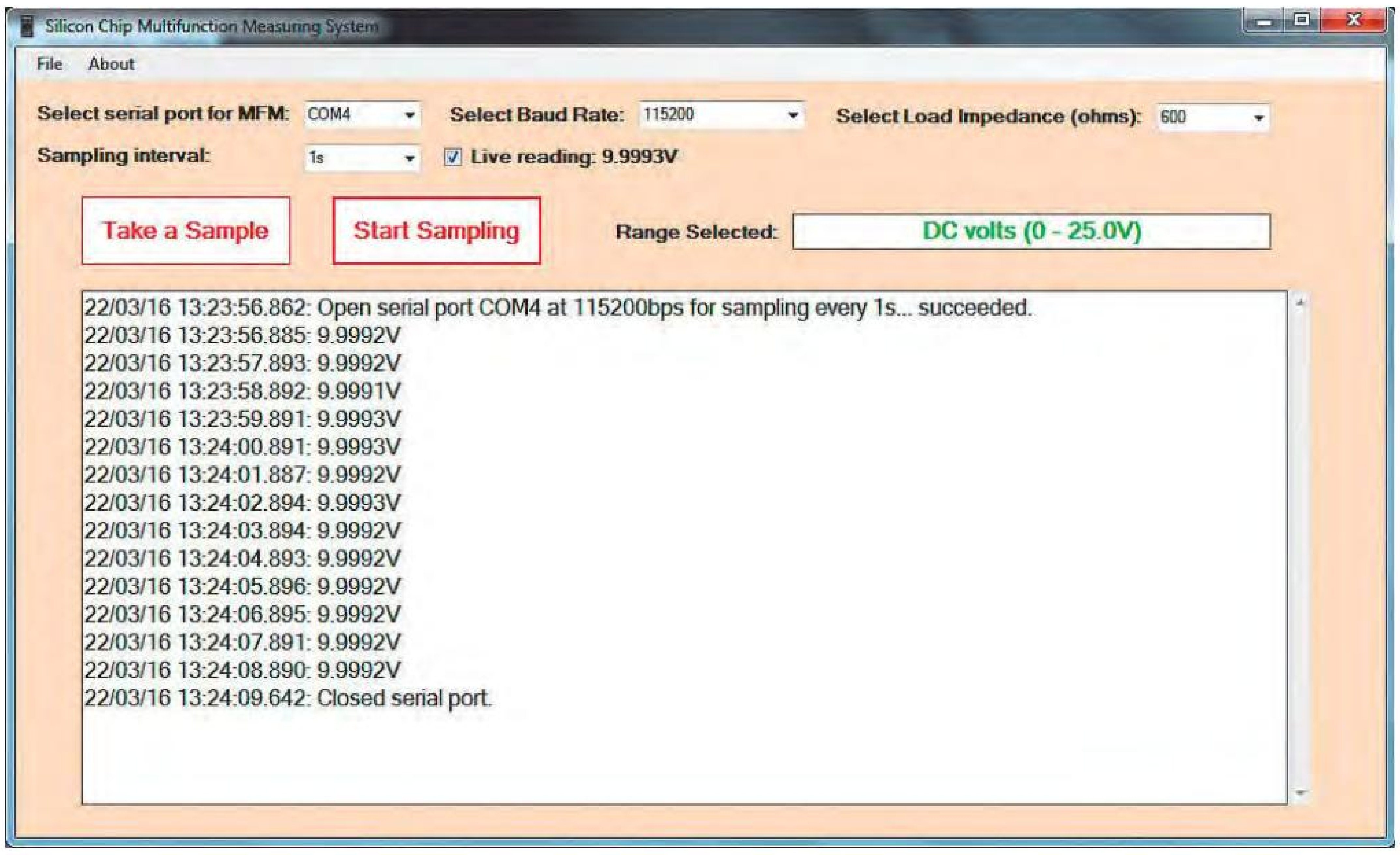
Fig.10: this diagram shows how to connect an RF signal to the *MFM RF Measuring Head*. Note that the signal is connected to a 50Ω load as well to the relevant input using a 'T' connector.

RF Level & Power range

This range is a bit simpler to calibrate since it's only necessary to adjust trimpot VR3 (Intercept Adjust) inside the companion *RF Measuring Head*.

This time, you will need an RF sinewave signal source (preferably unmodulated) and again some way of accurately measuring its level. You can either use an RF signal generator with an output meter and an attenuator or an uncalibrated RF oscillator or transmitter with a separate RF level meter to monitor its output.

The frequency of the generator/oscillator should be set to around 1MHz, or at least no higher than 10MHz.



Select serial port for MFM: COM4
Select Baud Rate: 115200
Select Load Impedance (ohms): 600
Sampling interval: 1s
☑ Live reading: 9.9993V
Range Selected: DC volts (0 - 25.0V)

```
22/03/16 13:23:56.862: Open serial port COM4 at 115200bps for sampling every 1s... succeeded.
22/03/16 13:23:56.885: 9.9992V
22/03/16 13:23:57.893: 9.9992V
22/03/16 13:23:58.892: 9.9991V
22/03/16 13:23:59.891: 9.9993V
22/03/16 13:24:00.891: 9.9993V
22/03/16 13:24:01.887: 9.9992V
22/03/16 13:24:02.894: 9.9993V
22/03/16 13:24:03.894: 9.9992V
22/03/16 13:24:04.893: 9.9992V
22/03/16 13:24:05.896: 9.9992V
22/03/16 13:24:06.895: 9.9992V
22/03/16 13:24:07.891: 9.9992V
22/03/16 13:24:08.890: 9.9992V
22/03/16 13:24:09.642: Closed serial port.
```

Fig.11: the display app automatically shows the range selected on the *MFM*, immediately to the right of the sampling buttons. It's shown here displaying a number of voltage measurements at one-second sampling intervals.

As before, here's the procedure you need to follow, step-by-step:

Step 1: plug the cable from the *RF Measuring Head* into the 3.5mm 'RF Head End' socket on the *MFM*.

Step 2: connect the *MFM* to your PC and check that it's operating correctly.

Step 3: launch the MFM Control & Display app, set it to communicate with the *MFM* via the listed COM port at 115,200 baud and with a load resistance of 50Ω.

Step 4: set the *MFM's* range switch S1 to the 'RF Level & Power' position.

Step 5: connect your RF signal source to the *RF Head's* input using an SMA 'T' connector, as shown in Fig.10. Also, fit a 50Ω dummy load with an appropriate power rating to the other end of the 'T' connector.

Step 6: select a short sampling interval and enable Live Reading. As before, the figures you now need to check are for dBV and Vrms. They will probably be either too high or too low, compared to the level set on your RF signal source.

Step 7: use a small screwdriver to adjust trimpot VR3 (Intercept Adjust) via the small hole in the top of the *RF Measuring Head* until the dBV and Vrms values are as close as possible to the level set by your RF signal source.

Points to note

When setting the level of your RF signal source, make sure that its output cable is terminated in a 50Ω load. Most signal generators are calibrated this way but if you have one that isn't, you can be fooled into setting the *MFM* to read high by up to 6dB.

Another point to note is that when calibrating the 'RF Level & Power' range, the RF signal source must be terminated at the input to the *MFM* head end. That's because if cables carrying RF signals are not terminated with the correct impedance at both ends, there will be reflections. As a result, standing waves can develop in the cable, leading to measurement errors.

This isn't necessary when calibrating the 'AF Level & Power' range. In fact, given the amount of power that may be dissipated in the load resistance, you will normally connect the load directly to the Device Under Test (DUT) using heavy cables and run a smaller, shielded cable from the output terminals of the DUT to the *MFM* input.

Load resistors

The main thing to bear in mind when making dBm or power measurements is that the *MFM* does not have inbuilt load resistors. This applies to both the Audio Level & Power range and the RF Level & Power range. It would have been very complicated to do this and would not have suited all situations, so **the *MFM* must be used with external load resistors for both these ranges**.

If you already have AF or RF dummy loads with adequate power ratings for the power levels you want to measure, these can be used without modification. On the other hand, if you do need to acquire one or more dummy loads of a particular impedance and/or power level, they can be purchased or built for minimum outlay and no modifications to the *MFM* itself will be required. For example, 4Ω and 8Ω wirewound resistors with ratings of 50W and 100W are relatively cheap and are available from multiple suppliers.

There is one further small point to remember when making RF level and/or power measurements via the *RF Measuring Head*: be sure to connect the *RF Head* to the *MFM* (ie, connect

What to do if you're missing a DLL

The Windows installer for the *MFM* software package includes a required set of DLLs (Dynamic Link Libraries), referred to as the 'C Runtime Library' (CRT for short). They contain support routines required by software developed using Microsoft Visual Studio using C or C++. When you run the installer we supply, it checks to see if you already have the required version of the CRT DLLs on your system and if not, installs them.

But Microsoft has recently changed the way the CRT DLLs work. To avoid having to install a whole new set of DLLs for software built using each different version of Visual Studio, they now supply a set of 'Universal CRT' DLLs with Windows. Developers then only need to bundle a smaller set of DLLs with their software, which in turn rely on the Universal CRT.

Windows 10 comes with these Universal CRT files out of the box, but for Vista, Windows 7 and Windows 8, they are instead installed by Windows Update. For some reason, it seems that some PCs still lack these files, even with all the latest updates installed. If you try to launch our software on such a PC, you get the following error message:

The program can't start because api-ms-win-crt-l1-1-0.dll is missing from your computer.
Try reinstalling the program to fix this problem.

If this happens, check that your PC has the latest updates installed. If so, you will need to download and install the Universal CRT files yourself. They can be found at the following location: **www.microsoft.com/en-us/download/details.aspx?id=50410**

If you're still using Windows XP (despite the fact that it's no longer supported!) this will almost certainly be necessary.

RF Measuring Head modification

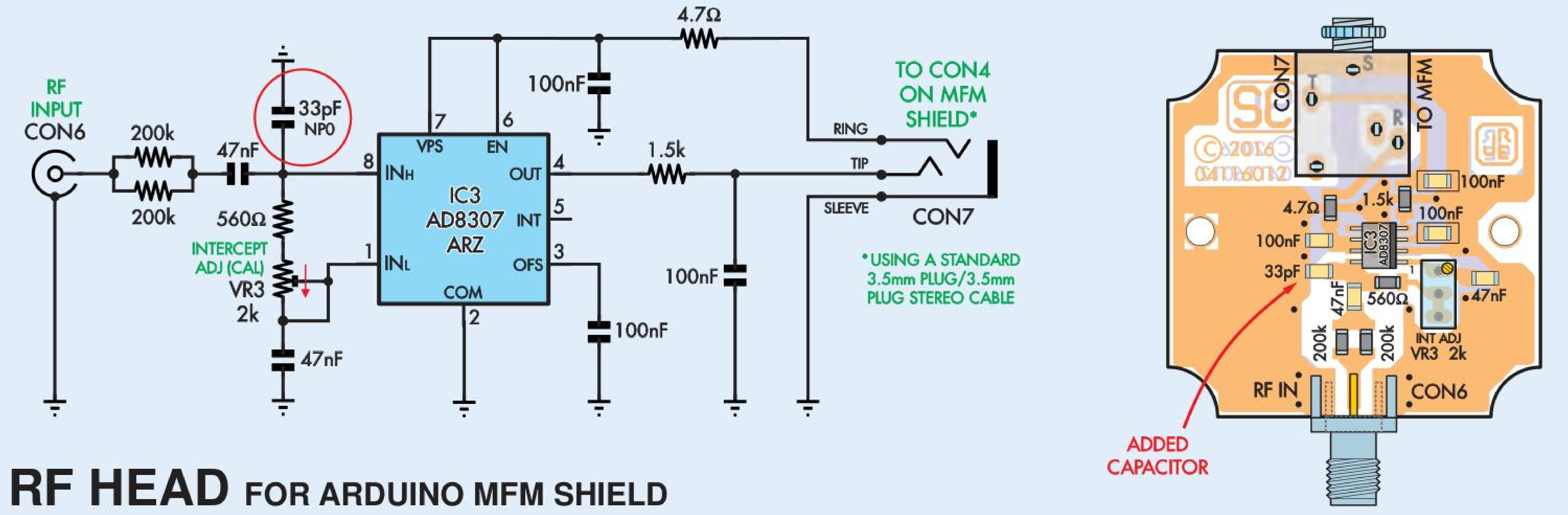


Fig.12: the *RF Measuring Head* needs to be modified by adding a 33pF NP0 capacitor between pin 8 (IN_H) of IC3 and ground, as shown here. This capacitor swamps the stray capacitance across the two 200kΩ input resistors and ensures that the *RF Measuring Head* remains accurate for frequencies above 10MHz.

Further testing of the *MFM's RF Measuring Head* has revealed the need for a 33pF NP0 capacitor to be added between the pin 8 (IN_H) of IC3 and ground.

Without this capacitor, the very small stray capacitance across the two paralleled 200kΩ input resistors causes the signal level into pin 8 of IC3 to increase as the input frequency rises above about 10MHz. Thus, the input voltage divider's division ratio gradually falls below its nominal low-frequency level of 158:1.

Adding a 33pF capacitor compensates for this stray capacitance by forming an additional, parallel capacitive voltage divider, thus maintaining the input division ratio at its correct level for higher frequencies. It ensures that the calibration of the *MFM's RF Measuring Head* is maintained up to the limit of the AD8307 log detector's measurement capability (around 500MHz).

Fig.12 shows the revised circuit and PCB layout diagrams for the *RF Measuring Head*. If you have the latest PCB version, just follow Fig.12 to build the unit as shown, with the extra capacitor.

Alternatively, if you have one of the earlier *RF Head* PCBs, it's quite easy to add the 33pF capacitor. First, scrape away a small patch of green resist coating from the top layer earth copper, to the left of pin 8 of IC3 and just below the 100nF bypass capacitor on pins 6 and 7. Tin this bared copper area (to provide for the capacitor's earth connection), then scrape away the green resist on the copper above the 47nF input capacitor (the one going to pin 8 of IC3) and tin this small area of bared copper as well.

We soldered a 1.5 x 2.5mm rectangle of flattened, thin (eg, 0.15mm) copper foil to the exposed copper to make a pad for the 33pF capacitor. However you could just solder the capacitor directly across the two areas of copper that are now exposed. Its final location should be very close to that shown in the revised PCB overlay diagram, Fig.12.

CON5 and CON7) before you plug the *MFM's* USB cable into your PC. The reason for this is that the +5V line can be briefly shorted to earth when these plugs are fitted into their sockets, so it's safer to make the connections before power is applied to the *MFM*.

Analysing and plotting data

The *MFM* Windows software saves sample data in a CSV format which can be loaded into Microsoft Excel, LibreOffice/OpenOffice Calc or just about any spreadsheet software. It's then a simple matter to plot or analyse this data.

For example, after opening a CSV file saved from the MFM app in Calc, simply click OK on the Import dialog and the data should appear, with column 'A' containing the time stamp for each sample, column 'B' the sample number (starting with 0 for the first sample in each sequence), column 'C' the number of milliseconds that each sample was taken relative to the first and the remaining columns ('D' and so on) containing the sample values.

If you want to plot a set of samples, first click on column 'C' just before the first sample you're interested in, which should read 'Milliseconds'. Then, shift-click on the data you want to plot in the last row, which may be in one of the columns titled 'V', 'dbV', 'Vrms' and so on.

Then, under the 'Insert' menu at the top of the window, go to the 'Object' sub-menu and click on 'Chart'. There are various types of chart to choose from, we suggest starting with 'X-Y (Scatter)'. You can then select either Points, Points and Lines or Lines and click Next twice. Select any data series you don't want to plot in the box at left and click 'Remove' to get rid of them. Then click Finish and the chart should appear. You can make further changes; see the documentation and internet forums for more details.

Note that both LibreOffice Calc and OpenOffice Calc are free downloads. They can also analyse this data, doing calculations such as variance analysis, correlations, moving averages and so on (as can Excel). Check the documentation of these software packages for more information.

Reproduced by arrangement
with SILICON CHIP
magazine 2017.
www.siliconchip.com.au

Precision 230V/115V 50/60Hz Turntable Driver

By John Clarke

POWER
12-15V DC IN
DEFAULT SLOWER FASTER
50/60Hz Precision Turntable Driver
230/115V AC OUT
STROBO

This *Precision Turntable Driver* will power belt-driven or idler driven turntables with 230VAC at 50Hz, or 115VAC at 60Hz. As a bonus, the turntable pitch is capable of being adjusted over a range of ±12%, which is great for music-teaching applications. It also enables you to adjust the music speed to obtain the correct number of beats per minute for dancing applications.

OK so it does all the above but why would you want it? The most obvious reason is if you have an imported American turntable which needs to run from a 115VAC 60Hz supply.

That's a real problem in the UK-where we have a 230VAC 50Hz mains supply. Sure, you could get a 230VAC to 115VAC step-down transformer to provide the correct drive voltage, but at 50Hz the turntable would run almost 17% slow and the motor would tend to overheat, making it unusable. So that's reason *numero uno*.

The second reason to consider building this *Precision Turntable Driver* is if you travel around the countryside and want to play records in your caravan or motor home when you are away from the 230VAC 50Hz supply.

Sure, you may have a 12V-to-230VAC inverter, but there is no guarantee that its frequency will be reasonably close to 50Hz, which can mean that the turntable may run noticeably fast or slow.

Realistically, most people are relatively insensitive to pitch errors, but small inverters can not only be incorrect in their frequency but can also change frequency according to the load. The same effect can occur with portable petrol generators.

Sinewave and modified square wave inverters can also have quite a high level of buzz and hash in their outputs – and this can be picked up by the very sensitive preamplifier needed for a magnetic cartridge.

Third, while it is fairly common for 'better' CD players to have a pitch control, which is useful for music and singing teachers, a variable speed facility on a turntable is (was) generally only available on expensive direct-drive models.

Now, with our *Precision Turntable Driver*, you can have this facility on any belt-driven or idler-driven turntable.

And if you are the disc jockey running dances, having a variable speed facility on a turntable is also very useful to obtain the correct beats per minute. For example, music for a Viennese Waltz should be at around 160 beats per minute; quite fast.

Finally, we should note that if you have an old belt-driven or idler-driven turntable, its speed may not be exactly correct, when checked with a strobe disc and our *Turntable Strobe* (see *EPE*, February 2017).

Unless you can perceive perfect pitch, any small error in speed is simply academic, but you do have the ability to make it *precisely* correct via the fine speed adjustments available on the *Precision Turntable Driver*.

The *Precision Turntable Driver* can be run from a 15V 2A DC supply or from a 12V battery. The battery options means that you can use it anywhere you don't have a mains supply.

With a 15V DC supply, the output will be close to 220VAC, or if you are operating a 110-120VAC powered turntable, the output will be close to 110V.

If you run from a 12V DC supply, the output will be less (at around 180VAC) but most turntable motors seem to run quite well at this lower voltage.

The *Precision Turntable Driver* is housed in a rugged diecast aluminium case with a DC socket, On/Off toggle switch and a red power LED at one end. At the other end is the 3-pin mains output socket.

If you want to use the speed adjust facility (without opening the case), you will also need to mount three small momentary-contact buttons on the lid.

Block Diagram

Fig.1 shows the block diagram for the *Precision Turntable Driver*. A 5-bit digital to analogue (D-to-A) converter is used to generate a 32-step sinewave signal. This is shown as the yellow trace in the screen grab, Scope1, and it is close to 5V peak-to-peak.

The waveform is then amplified and filtered by op amp IC2a and the result is the green trace, with an amplitude of just over 14V peak-to-peak.

The signal is then fed to op amp IC2b, which functions as a 12dB/octave low-pass filter to remove the 32 steps and produce a smooth sinewave.

This can be seen in screen grab Scope2 as the yellow trace. The waveform is then inverted in op amp IC2c, as shown in the green trace.

The two signals are then buffered by complementary MOSFET driver stages which provide the high-current drive for the transformer. The resultant drive signals are depicted in the yellow and green traces in screen grab Scope3.

The drive signal across the transformer primary windings is shown in the mauve trace, which is the difference (MATH function) of the two buffered drive signals. Its amplitude is a little less than twice that of the drive signals.

The 9V primary windings of the transformer are connected in parallel to be driven by the MOSFET buffer stages. The transformer steps up the output to drive the turntable.

The secondary of the transformer has two 115V windings, which are connected in series for a nominal 230VAC output (for turntables which require a 50Hz mains supply) and in parallel for a nominal 115VAC output (for turntables which require a 60Hz mains supply).

Losses in the transformer mean that it does not deliver the full 115VAC output across each winding, even though the 9V windings are driven at more than 10VAC.

The (unloaded) output waveform from the transformer is shown in Scope4. The actual voltage delivered to the turntable motor will depend on the DC supply voltage fed to the circuit and the loading of the motor.

Circuit details

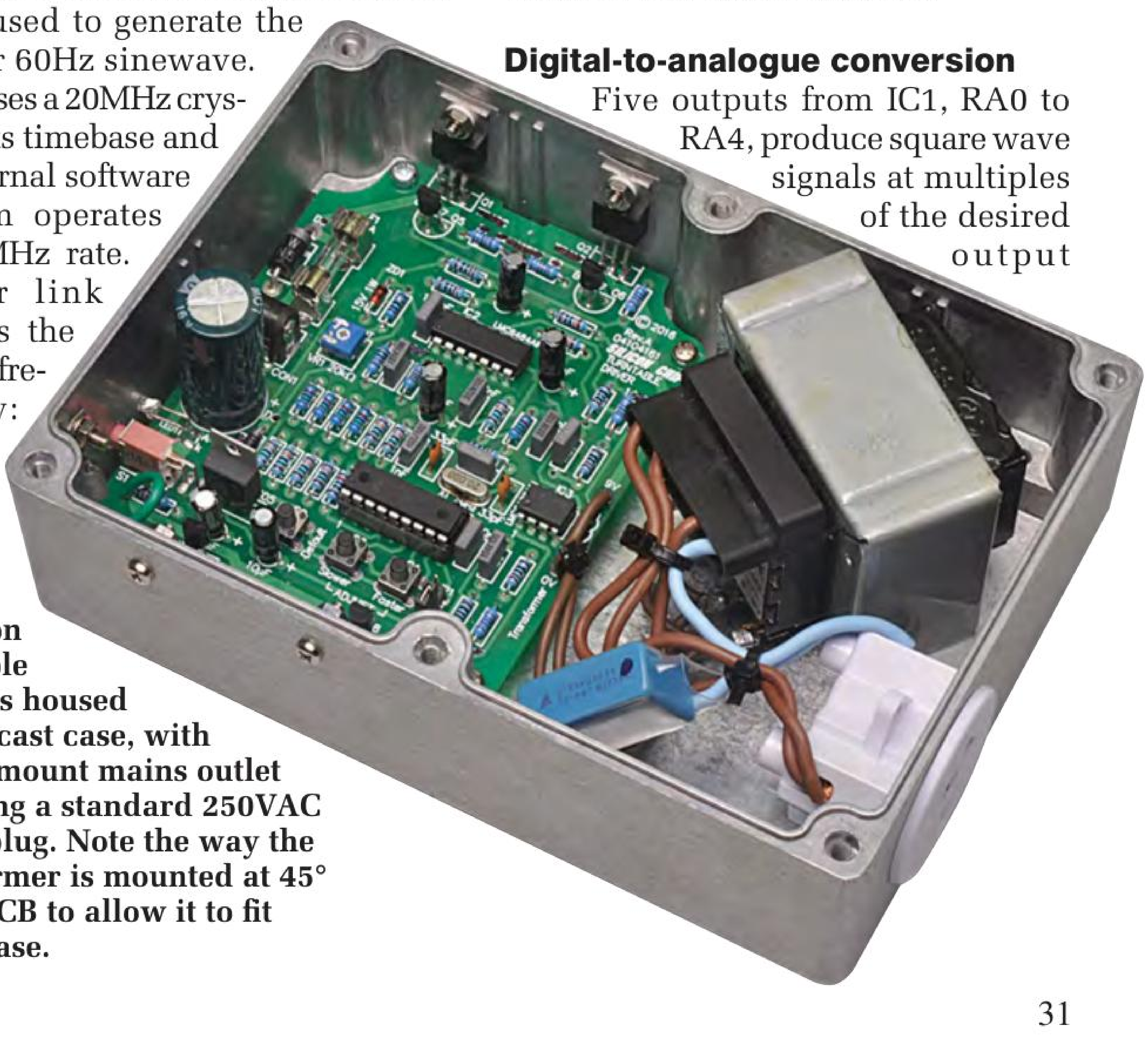
The complete circuit of the *Precision Turntable Driver* is shown overleaf (Fig.2). It is split into two sections: on the left (top) is the power supply and signal generator while the MOSFET output stages and step-up transformer are on the right (bottom).

Referring now to the power supply section, IC1 (a PIC16F88 microcontroller) is used to generate the 50Hz or 60Hz sinewave.

IC1 uses a 20MHz crystal for its timebase and the internal software program operates at a 5MHz rate. Jumper link JP1 sets the output frequency: with the jumper open it's 50Hz and with a jumper shunt inserted it's 60Hz.

Features

- **Can be used with 12 to 15V DC supply or a 12V battery**
- **230VAC or 115VAC (nominal) sinewave output**
- **50Hz or 60Hz output frequency**
- **Crystal accuracy**
- **Pitch control (frequency adjustment)**



The Precision Turntable Driver is housed in a diecast case, with a flush-mount mains outlet accepting a standard 250VAC mains plug. Note the way the transformer is mounted at 45° to the PCB to allow it to fit in the case.

Momentary-contact switches S3 and S4 provide the up and down frequency adjustment. The frequency is changed in 0.02Hz steps at a rate of four per second, while a switch is held pressed. Pressing default switch (S2) returns the frequency to the precise 50Hz or 60Hz setting (depending on the state of JP1).

All the inputs associated with JP1, S2, S3 and S4 include separate internal pull-ups that keep the inputs high (at 5V). The inputs are pulled low (0V) when there is a shorting link in JP1 or when a switch is pressed.

S2-S4 can be mounted on the lid via flying leads from CON2 if you wish to be able to adjust the speed without opening the box. In this case, the internal S2-S4 can be omitted.

Digital-to-analogue conversion

Five outputs from IC1, RA0 to RA4, produce square wave signals at multiples of the desired output

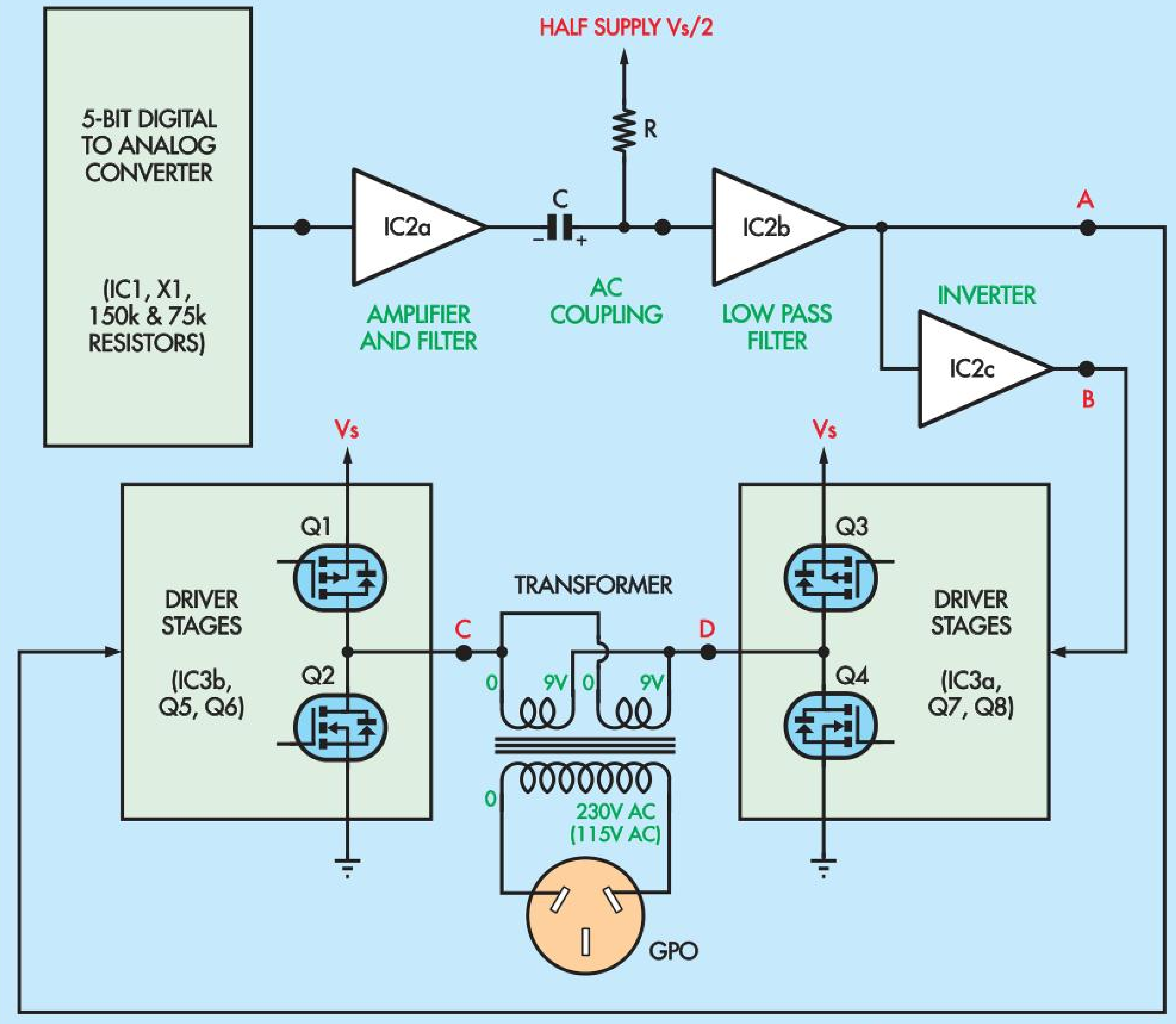

HALF SUPPLY Vs/2
R
5-BIT DIGITAL TO ANALOG CONVERTER
(IC1, X1, 150k & 75k RESISTORS)
IC2a
AMPLIFIER AND FILTER
C
AC COUPLING
IC2b
LOW PASS FILTER
A
INVERTER
IC2c
B
Vs
Q1
Q2
DRIVER STAGES
(IC3b, Q5, Q6)
TRANSFORMER
C
D
0
9V
0
9V
0
230V AC (115V AC)
GPO
Vs
Q3
Q4
DRIVER STAGES
(IC3a, Q7, Q8)

Fig.1: the *Precision Turntable Driver* circuit generates a clean sinewave signal and feeds it to a Class-B amplifier driving a step-up transformer to produce 220VAC or 115VAC.

frequency. These outputs are fed to the 5-bit digital-to-analogue converter (DAC) which is actually a standard R/2R resistor ladder (comprising 150kΩ and 75kΩ resistors). This generates the 32-step sinewave signal.

The R/2R resistor ladder makes a cheap DAC and five bits is about the maximum number that can be used when only 1% resistors are used. It is quite sufficient for this application.

The DAC output is filtered with a 1nF capacitor to remove switching glitches. The resulting 5V sinewave is amplified using IC2a, which is one quarter of an LMC6484AIN quad rail-to-rail op amp.

Trimpot VR1 is used to adjust the output level to produce the maximum undistorted sinewave signal.

Following this, the signal from IC2a is AC-coupled with a 10µF capacitor and is now referenced via a 10kΩ resistor to half supply ($V_{CC}/2$) which is derived with two 10kΩ resistors connected across the V_{CC} supply and then buffered using op amp IC2d. Note that the supply to IC2 (and IC3) comes via a 10Ω resistor and is clamped to 15V using Zener diode ZD1. This is to protect the op amps that are rated for a maximum rail voltage of 16V. This clamped rail is marked 'V_{CC}'.

IC2b and its associated resistors and capacitors form a 2-pole Sallen-Key low-pass filter that rolls off above 160Hz at 12dB/octave.

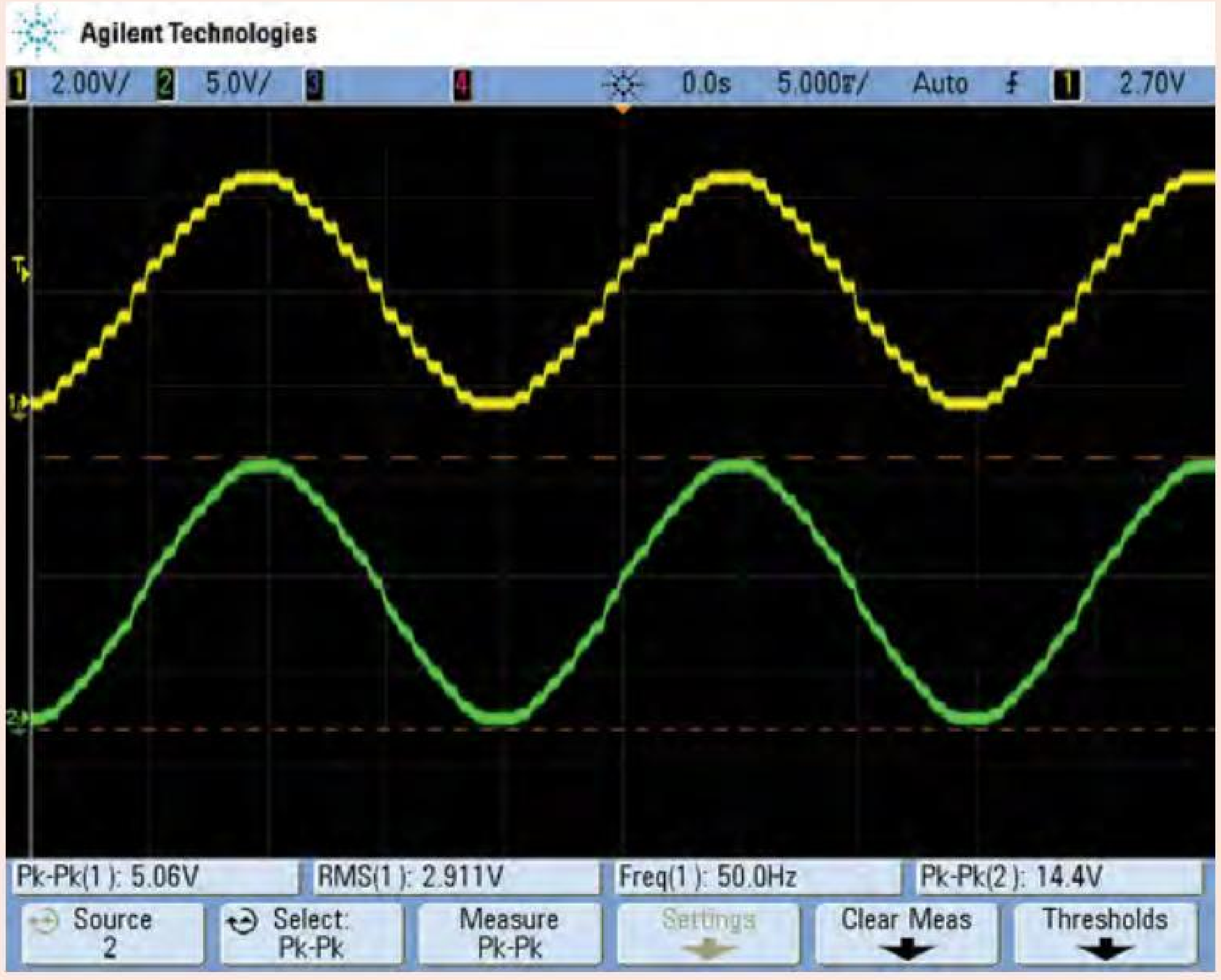
The filter only affects the high frequency components of the 32-step generated sinewave which are multiples of 32 × 50Hz or 1.6kHz (or 32 × 60Hz or 1.92kHz).

IC2b's output is then inverted by op amp IC2c to produce a complementary waveform (ie, 180° out of phase).

Transformer drive circuit

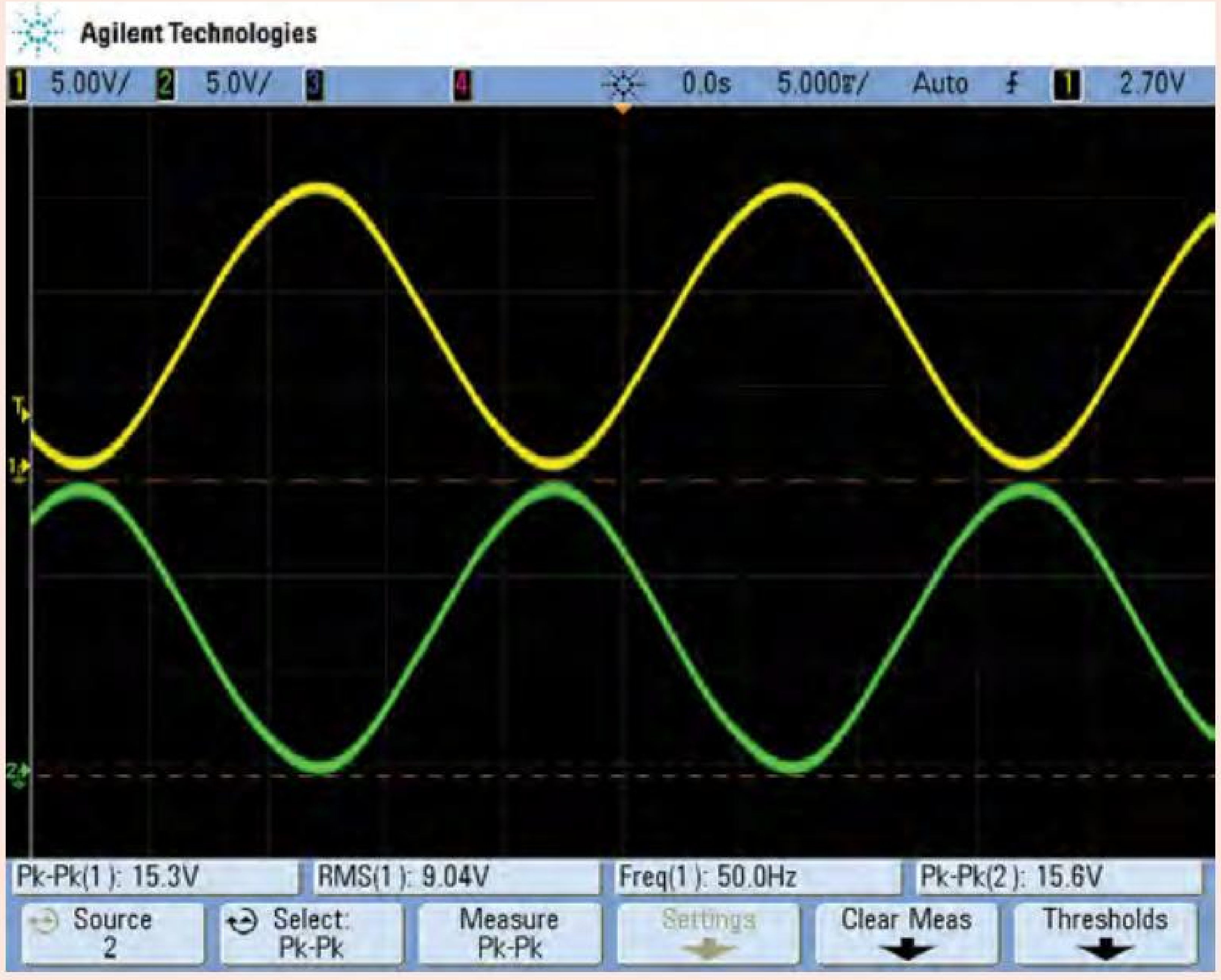
We need complementary drive signals for the transformer drive circuit which are shown in Fig.2 (labelled 'A' and 'B'). These signals are fed to non-inverting buffer stages IC3a and IC3b, which in turn are connected to the complementary output stages.

Let's just describe the lefthand side of the power supply circuit whereby


Agilent Technologies
1 2.00V/ 2 5.0V/ 3 4
0.0s 5.000ms/ Auto 1 2.70V
Source 2
Select: Pk-Pk
Measure Pk-Pk
Settings
Clear Meas
Thresholds

Pk-Pk(1): 5.06V RMS(1): 2.911V Freq(1): 50.0Hz Pk-Pk(2): 14.4V

Scope1: The stepped sinewave from the 5-bit DAC is shown in the yellow trace. The steps are smoothed out by the first op amp low-pass filter and the result is the green trace.


Agilent Technologies
1 5.00V/ 2 5.0V/ 3 4
0.0s 5.000ms/ Auto 1 2.70V
Source 2
Select: Pk-Pk
Measure Pk-Pk
Settings
Clear Meas
Thresholds

Pk-Pk(1): 15.3V RMS(1): 9.04V Freq(1): 50.0Hz Pk-Pk(2): 15.6V

Scope2: The smooth waveform from the low-pass filter (yellow trace) is inverted by op amp IC2c to produce the complementary waveform shown in the green trace.

IC3b drives complementary transistors Q5 and Q6, followed by complementary MOSFETs Q1 and Q2. Q1 is an IRF9540 P-channel MOSFET, while Q2 is an IRF540 N-channel type. The righthand side of the circuit is identical.

These stages operate in the same way as a Class-B audio amplifier and can simply be regarded as a unity-gain buffer.

More particularly, just as in a Class-B output stage, there is no quiescent current which means that it does produce some crossover distortion and while no-one will ever hear that crossover distortion we have incorporated biasing to minimise it.

The biasing is provided by the two diodes (D3 and D4) between the bases of transistors Q5 and Q6, with the current through the diodes provide by the 22kΩ resistor from V_{CC}. This current is about 300mA or so and the resultant bias voltage between the bases of Q5 and Q6 is insufficient (at around 1.1V in total) to cause them to conduct. However, that small amount of bias is enough to provide a significant reduction in crossover distortion but not enough to eliminate it.

Why do we care? It is simply because the crossover distortion was causing significant inflections in the output waveform on the secondary side of the transformer and we judged it worthwhile to minimise it.

A 1.5nF capacitor between ground and the tied-together transistor bases is included to reduce the rate at which the transistors can switch on and off. This prevents high frequency instability in the stage.

So we have the complementary signals at A and B being fed through the Class-B output stages and then connected to the paralleled 9V windings of the transformer. The actual maximum undistorted drive voltage from each Class-B output stage, assuming V_{CC} is 15V DC, is close to 5.1V RMS (14.43V peak-to-peak) and that gives a total AC voltage across the 9V windings of 10.2V.

The two 115V windings of the transformer are connected in series to provide a nominal 230VAC output (for turntables that require a 50Hz supply). For turntables that require a 60Hz 110VAC supply, the two 115V windings are connected in parallel rather than in series.

Because the transformer is a highly inductive load, especially when it is unloaded, its primary current lags the voltage by almost 90° and this would cause substantial heating of the MOSFETs. This 'power factor' problem is corrected by the 470nF (or 2.2µF for 115VAC) capacitors connected across the transformer output.

Assembly procedure

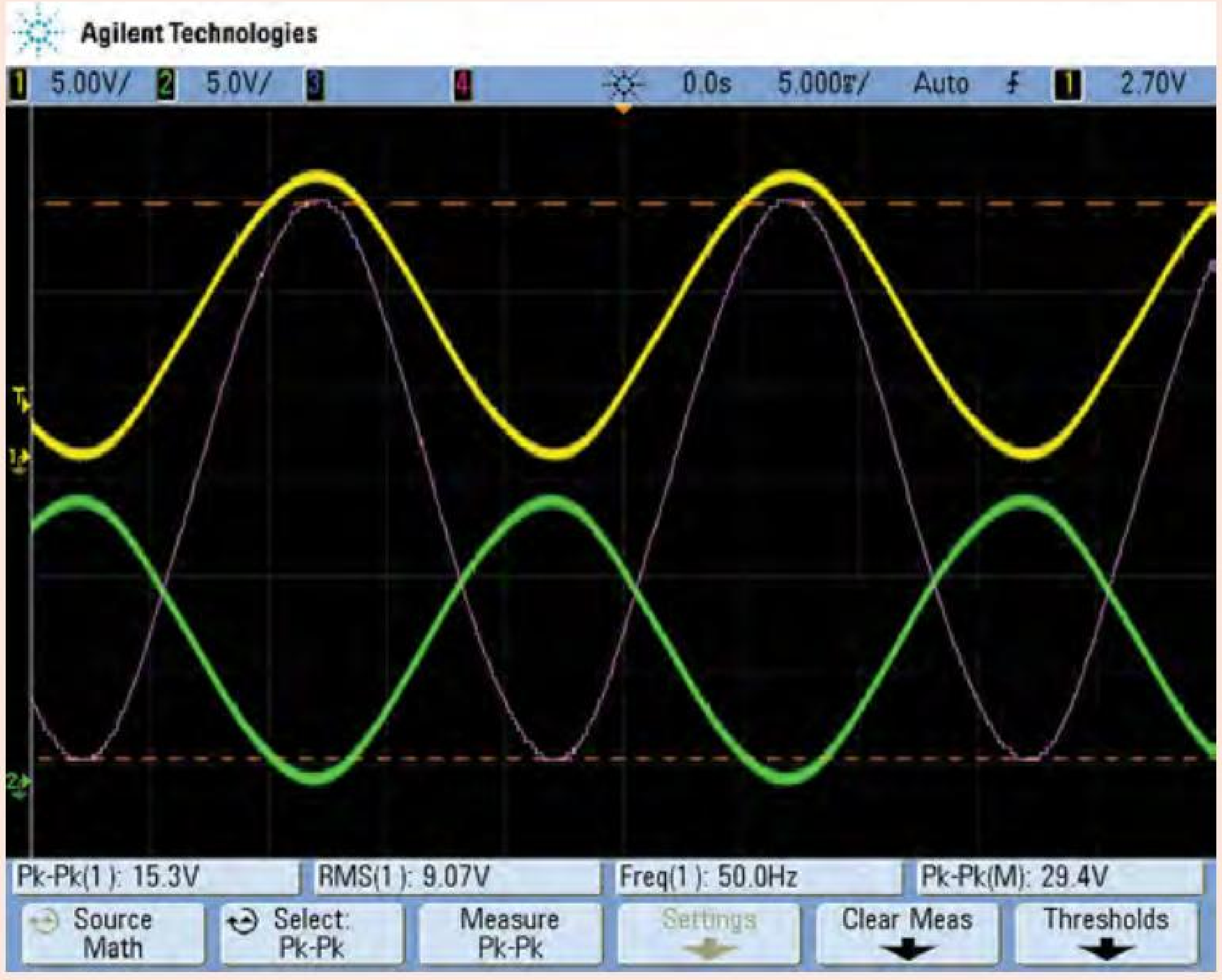
The *Precision Turntable Driver* is built on a PCB, available from the *EPE PCB Service*, (coded 04104161) measuring 84.5 × 112mm. It is housed in a diecast box that measures 171 × 121 × 55mm. The board is designed to be mounted on two of the integral mounts within the box and the outline of the PCB is shaped so that it fits neatly inside it.

Specifications

- **Rating: 20W @ 220VAC or 110VAC (nominal)**
- **Input Supply: 12-15VDC at 2A**
- **Output waveform: Sinewave**
- **Output Voltage: 220VAC or 110VAC with a 15V supply**
- **Output regulation: 9% from no load to 15W**
- **Frequency accuracy: ±50 ppm (ie, ±0.005%)**
- **Pitch control: ±12%**
- **Frequency adjustment for 50Hz: 41.5Hz to 56Hz in approximately 0.02Hz steps**
- **Frequency adjustment for 60Hz: 50Hz to 67.2Hz in approximately 0.02Hz steps**
- **Default button: Restores the output frequency (JP1) setting to 50Hz or 60Hz**

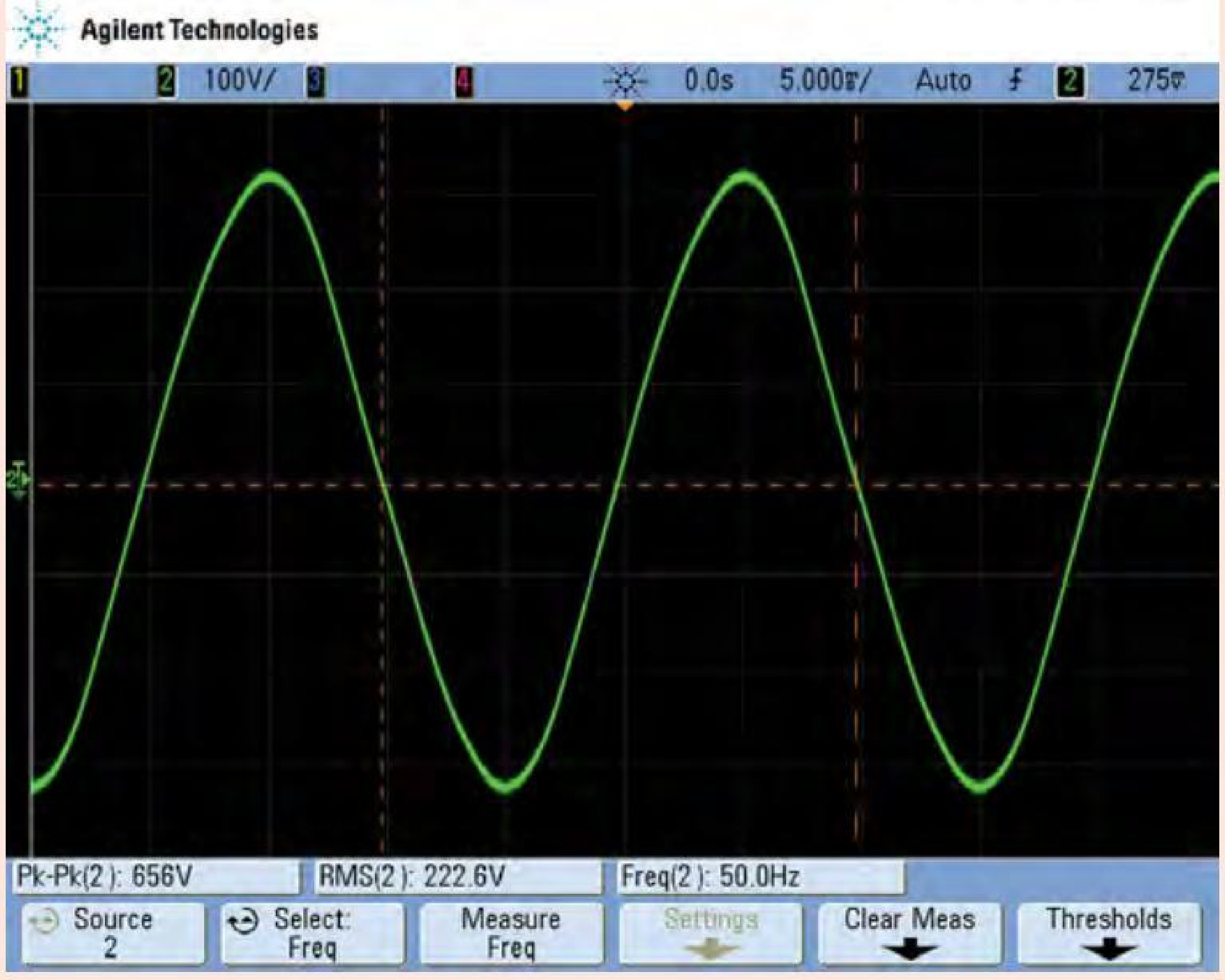
Fig.3 shows the parts layout on the PCB. Assembly can begin with installation of the resistors; it is a good idea to use a DMM to check each value as it is installed.

Follow this by installing diodes D1



Pk-Pk(1): 15.3V
RMS(1): 9.07V
Freq(1): 50.0Hz
Pk-Pk(M): 29.4V

Scope3: the complementary sinewave signals from the MOSFET Class-B amplifier stages are effectively added to drive the transformer primaries. Its amplitude is the sum of the two signals (mauve trace).



Pk-Pk(2): 656V
RMS(2): 222.6V
Freq(2): 50.0Hz

Scope4: the unloaded output from the two 115VAC trans-former windings connected in series. It is 222.6VAC or 656V peak-to peak. Note that this signal is much cleaner than the normal mains supply in homes, offices and factories.

to D6 and Zener diode ZD1. These must be mounted with the orientation shown.

Install IC1's socket next, followed by IC2 and IC3. Check that the orientation is correct before soldering each in place. Then install 20kΩ trimpot VR1 (it may be marked as 203). Switches S1 to S4 can be installed now, along with the DC socket (CON1). Note our earlier comments about S2-S4.

Install Q5, Q6, Q7 and Q8, making sure Q5 and Q7 are BC337s and Q6 and Q8 are BC327s. Leave MOSFETs Q1 -Q4 off for the moment.

When installing the fuse clips, they must go in with their retaining tabs toward the outside ends, otherwise you will not be able to fit the fuse later on.

Better still, clip the fuse into the fuse clips first before installing the clips into the PCB holes.

Next, install the capacitors, ensuring the electrolytic types are placed with the correct polarity.

Now place MOSFETs Q1, Q2, Q3 and Q4, taking care to fit the correct MOSFET in each location. These are positioned so that the mounting hole centre in each tab is about 22mm above the PCB. In every case, the metal tab must go towards the outside edge of the board.

The LED is mounted so that it can protrude through a hole in the end of the box. The leads are inserted with the longer anode (A) lead oriented as shown. If bent over, the LED can be set about 5mm above the PC board.

Connect a short (20mm) length of wire to the GND terminal on the PCB and terminate the other end to a solder lug.

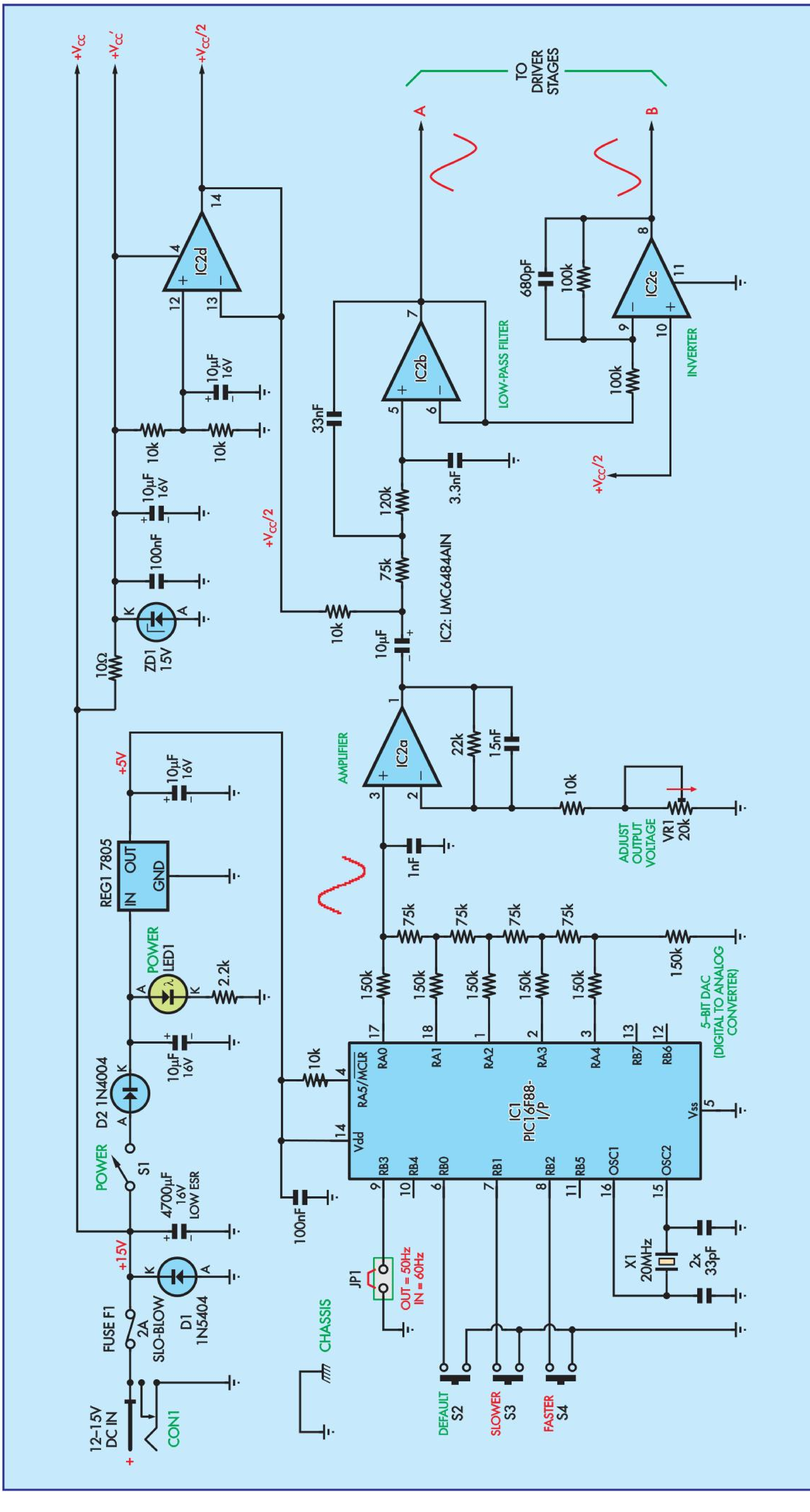
Also solder two 50mm lengths of wire to the 0V and 9V pads ready for connection to the transformer.

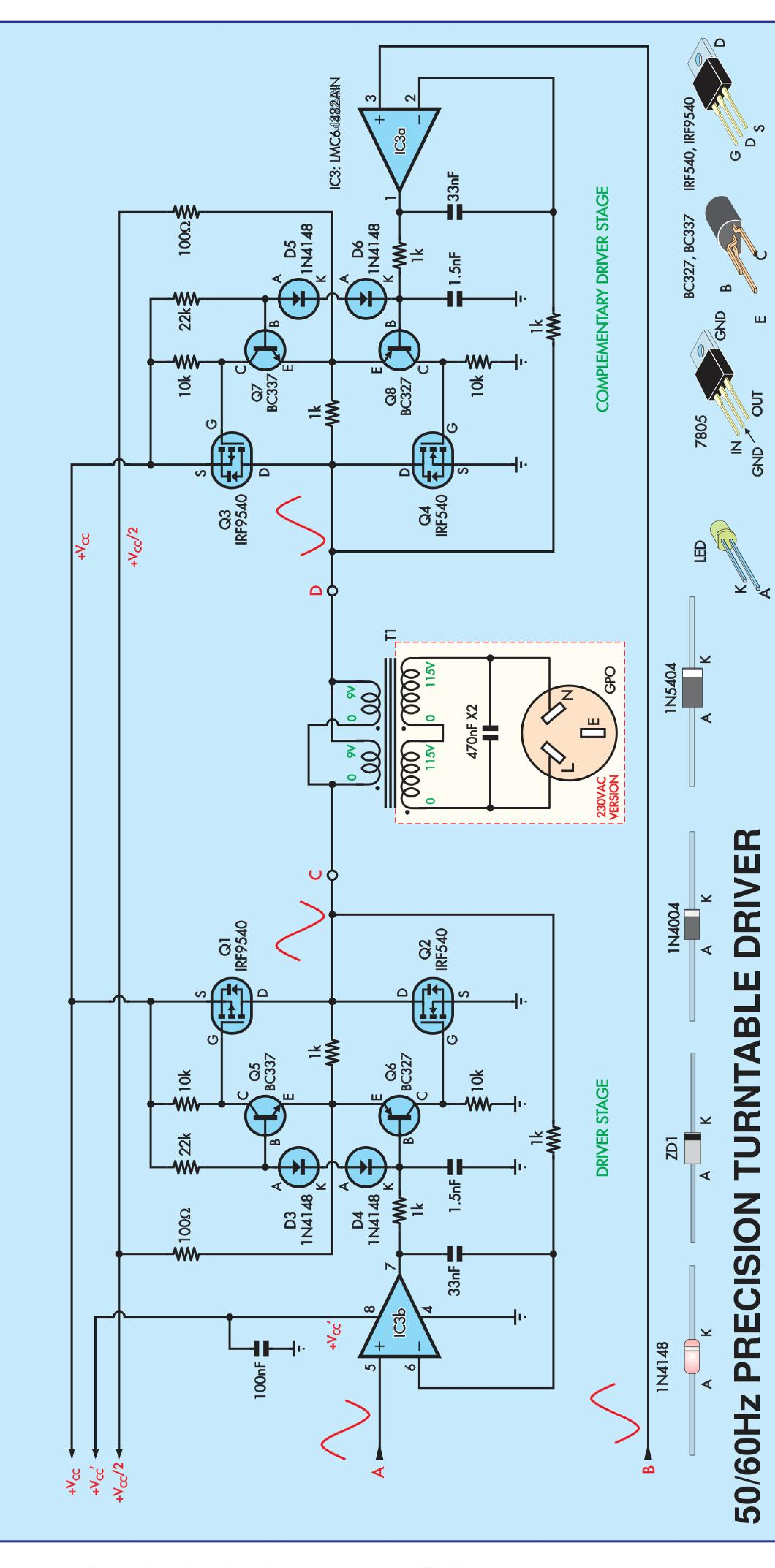
Case drilling

Use the drilling template in Fig.5 to mark out and drill the holes for the power switch S1, LED1, the DC socket hole and earth screw at one end of the case, and the surface-mounted mains AC socket at the opposite end.

The larger hole for the mains socket can be drilled out using a series of small holes around the perimeter and then, after knocking the inside piece out, filing to shape.

Place the PCB inside the case inserting the switch(es) and LED into their holes. Mark out the hole positions for the two PCB mounting positions that


+V_CC
+V_CC'
+V_CC/2
TO DRIVER STAGES
A
B
IC2d
IC2b
IC2c
IC2a
LOW-PASS FILTER
INVERTER
AMPLIFIER
IC2: LMC6484AIN
680pF
100k
100k
33nF
3.3nF
120k
75k
10k
10µF
22k
15nF
10k
ADJUST OUTPUT VOLTAGE
VR1 20k
1nF
75k
150k
5-BIT DAC (DIGITAL TO ANALOG CONVERTER)
IC1 PIC16F88-I/P
RA0
RA1
RA2
RA3
RA4
RB7
RB6
RA5/MCLR
Vdd
Vss
RB3
RB4
RB0
RB1
RB2
RB5
OSC1
OSC2
X1 20MHz
2x 33pF
JP1
OUT = 50Hz IN = 60Hz
DEFAULT S2
SLOWER S3
FASTER S4
CHASSIS
100nF
10k
10µF 16V
10k
10k
10Ω
ZD1 15V
100nF
+5V
REG1 7805
IN OUT GND
POWER LED1
2.2k
D2 1N4004
POWER S1
4700µF 16V LOW ESR
+15V
D1 1N5404
FUSE F1 2A SLO-BLOW
12–15V DC IN
CON1
K
A


+VCC
+VCC'
+VCC/2
A
B
C
D
IC3: LMC6482AIN
IC3a
IC3b
100Ω
22k
10k
1k
1.5nF
33nF
100nF
D3 1N4148
D4 1N4148
D5 1N4148
D6 1N4148
Q1 IRF9540
Q2 IRF540
Q3 IRF9540
Q4 IRF540
Q5 BC337
Q6 BC327
Q7 BC337
Q8 BC327
T1
9V
115V
470nF X2
GPO
230VAC VERSION
DRIVER STAGE
COMPLEMENTARY DRIVER STAGE
1N4148
ZD1
1N4004
1N5404
LED
7805
IN GND OUT
BC327, BC337
IRF540, IRF9540
G D S
A K
B E C

50/60Hz PRECISION TURNTABLE DRIVER

Fig.2: the top section of the circuit shows the micro and 5-bit DAC, low-pass filter and inverter stage. Its complementary sinewave signals are fed to the Class-B output stages shown immediately above. Note the back-to-front transformer.

require 9mm stand-offs and orient the transformer diagonally as shown in the photos and diagram, and mark out the mounting hole positions.

Drill out the holes for the stand-offs to 3mm in diameter and drill out the transformer mounting holes at 4mm in diameter.

Place the PCB in position, temporarily mounting this on the integral stand-offs in the box and on the 9mm spacers. Then mark the positions for Q1, Q2, Q3 and Q4 by marking where the metal tab holes of each are located when held against the side of the box.

Remove the board and drill these mounting holes to 3mm, then use an oversize drill to remove any metal swarf so that the area around each hole is perfectly smooth.

This is necessary to prevent punch-through of the insulating washer.

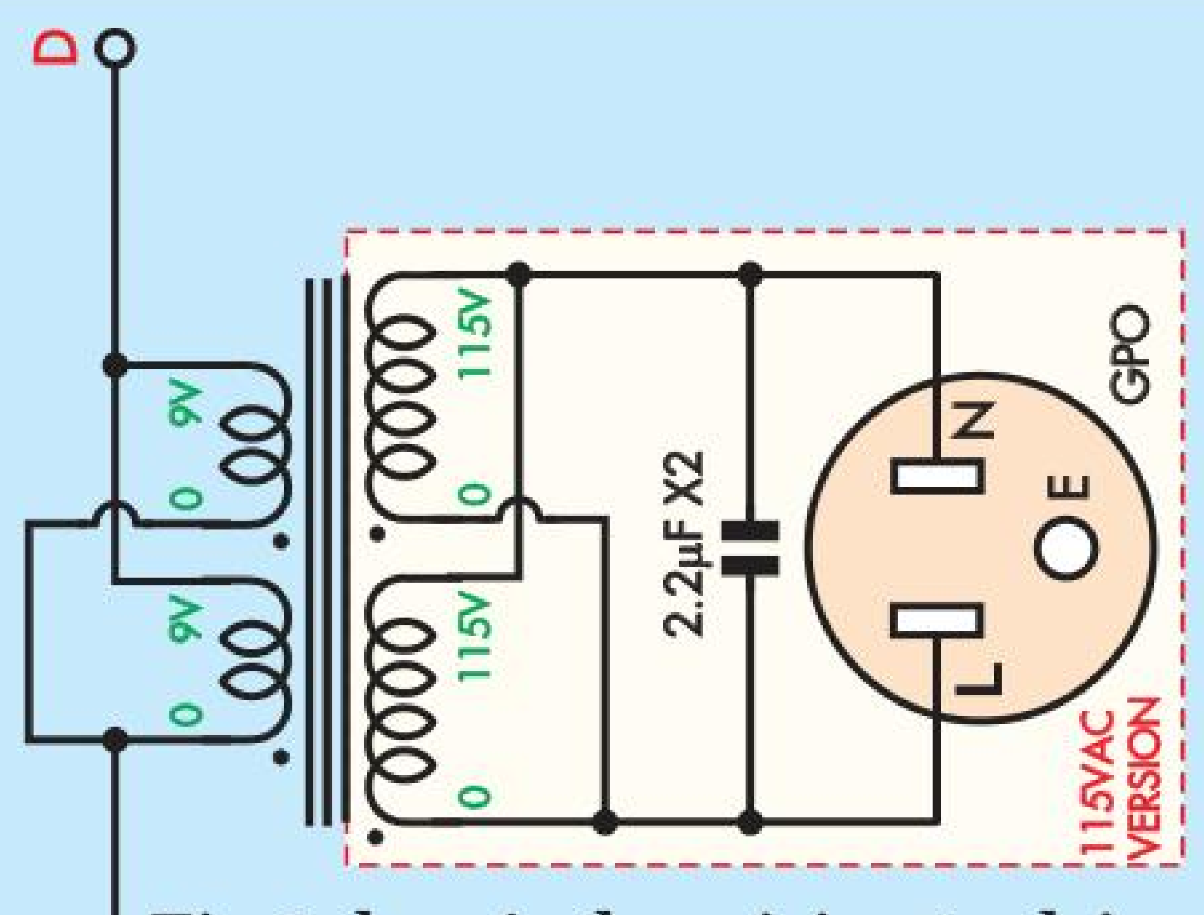

D
C
9V
115V
0
2.2µF X2
GPO
N
E
L
115VAC VERSION

Fig.3: here's the wiring to drive a 115VAC, 60Hz turntable with the two windings connected in parallel. Note the change in capacitor across the windings; also note JP1 will need to be set for 60Hz operation.

Reinsert the board into the case. Mount the transformer using M4 screws and nuts and mount the PCB using the screws supplied with the enclosure for the two mounting points in the corners.

The stand-offs are secured to the base of the case using countersunk M3 × 6mm screws (or machine screws) and machine screws (M3 × 6mm) to secure the PCB.

Then attach the TO-220 devices to the sides of the case as shown in Fig.7, using the M3 × 10mm screws. Note that it is necessary to isolate each device tab from the case using an insulating washer and insulating bush.

Once they have been installed, use a digital multimeter on a low-ohms range to confirm that the metal tabs are indeed isolated from the metal case. If a low resistance reading is measured, check that the silicone washer for that particular TO-220 device has not been punctured and that the insulation bush is not damaged.

Also connect the earth lug to the case using an M3 × 10mm screw, star washer and nut. The adhesive rubber feet can now be attached.

Wiring it up

Follow the wiring diagram of Fig.6 to connect up the transformer and socket (marked 'GPO' or general power outlet). Make sure 250VAC mains-rated wire is used and you must use the terminal shroud for the high voltage terminals (at the two 0-115V winding connections) so these are covered over.

Wire the 115V windings in series for 230VAC and in parallel for 115V. Note the different capacitor value connected across the mains for the 230VAC (470nF X2) and 115V (2.2µF X2) versions.

Two wires each connect to the live and neutral GPO terminals. One is from the transformer and the other from the mains-rated capacitor. The capacitor and wire connections are encased in some heatshrink tubing for insulation.

Note also that the earth terminal on the GPO is left disconnected. The 230VAC wiring is anchored with cable ties as shown.

Set-up procedure

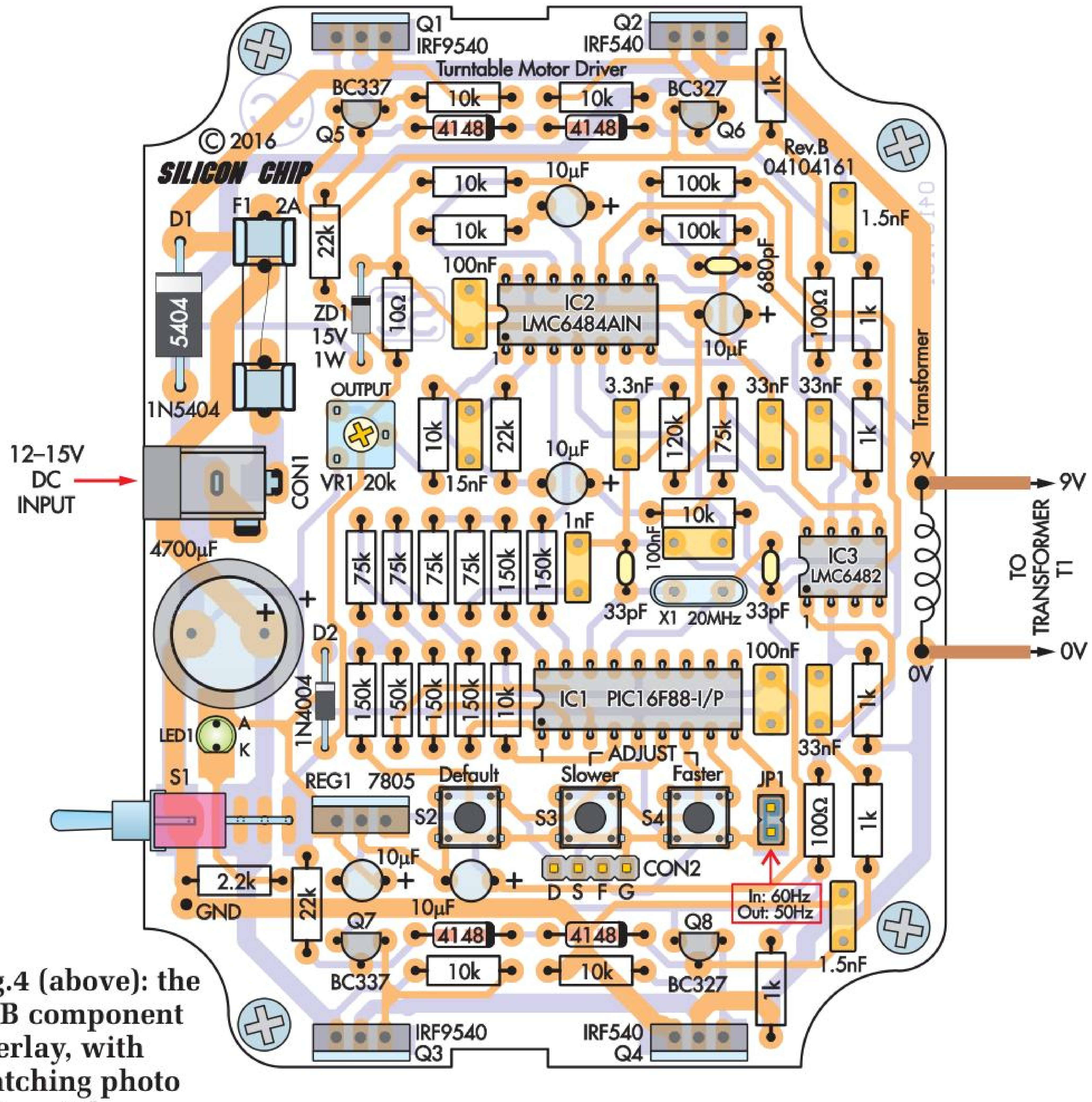
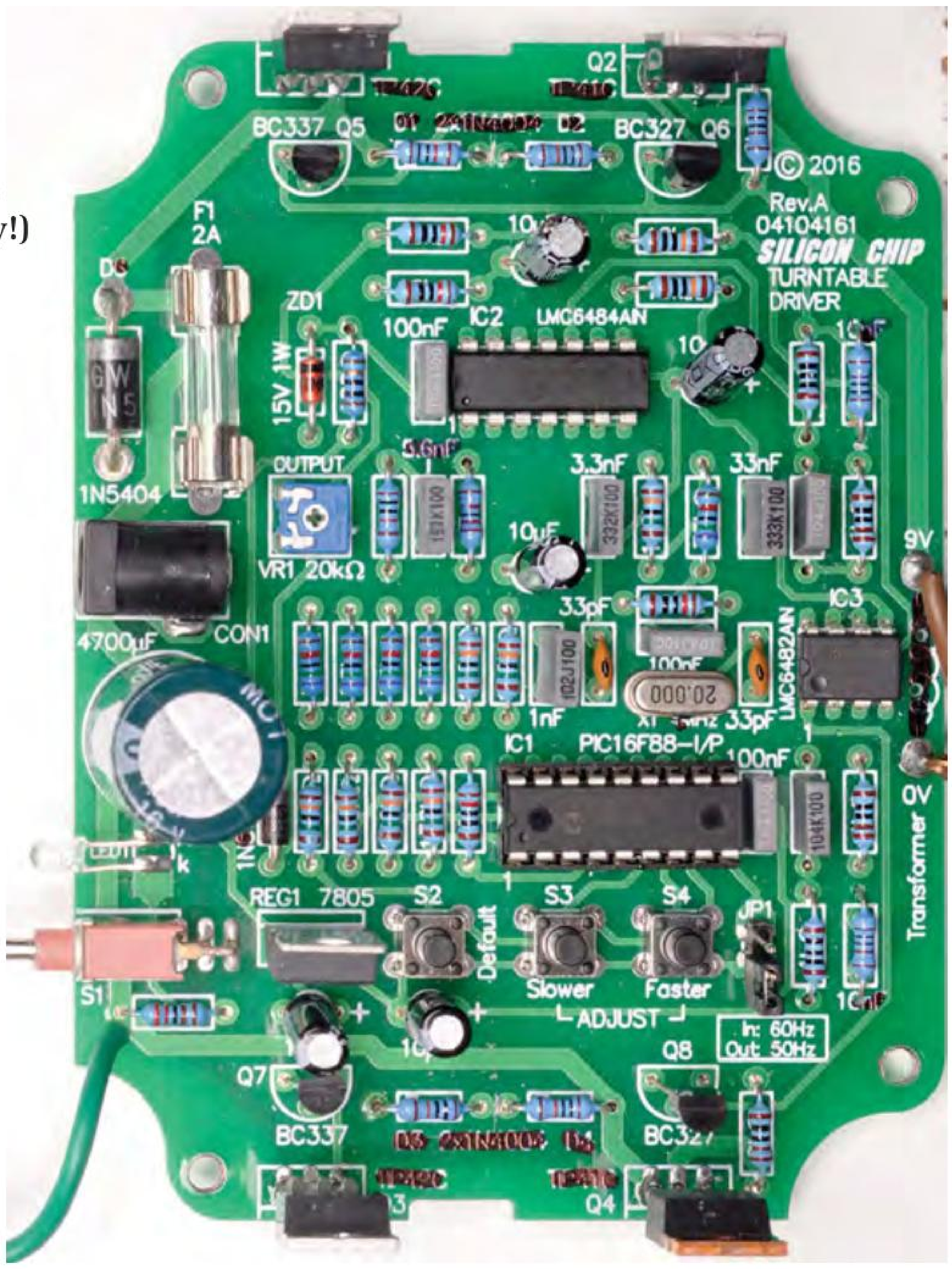

Q1
IRF9540
Q2
IRF540
Turntable Motor Driver
BC337
10k
10k
BC327
1k
Q5
4148
4148
Q6
© 2016
Rev.B
04104161
SILICON CHIP
10µF
10k
100k
F1 2A
1.5nF
D1
22k
10k
100k
100nF
680pF
5404
ZD1
15V
1W
10Ω
IC2
LMC6484AIN
10µF
100Ω
1k
1N5404
OUTPUT
3.3nF
33nF
33nF
Transformer
12–15V
DC
INPUT
CON1
VR1 20k
10k
22k
10µF
120k
75k
1k
9V
15nF
9V
4700µF
1nF
10k
75k
75k
75k
75k
150k
150k
100nF
IC3
LMC6482
TO
TRANSFORMER
T1
33pF
X1 20MHz
33pF
0V
D2
100nF
0V
1N4004
150k
150k
150k
150k
10k
IC1 PIC16F88-I/P
1k
LED1
A
K
ADJUST
33nF
S1
REG1 7805
Default
Slower
Faster
JP1
S2
S3
S4
100Ω
1k
10µF
2.2k
CON2
D S F G
GND
22k
10µF
In: 60Hz
Out: 50Hz
Q7
4148
4148
Q8
1.5nF
BC337
10k
10k
BC327
1k
IRF9540
Q3
IRF540
Q4

Fig.4 (above): the PCB component overlay, with matching photo below. (The photo shows an earlier prototype board with minor component differences. If in doubt, use the PCB component overlay!)



Turntable Strobe

Turntable Strobe

The *Turntable Strobe*, featured in the February 2017 issue, is perfect for ensuring accurate speed with the *Precision Turntable Driver*. If your platter doesn't have strobe markings (as this one does) a Strobe Disc, suitable for both 50Hz and 60Hz, is available from the Silicon Chip Online Shop for $10.00 (see below) (www.siliconchip.com.au/shop/19/3273)

SILICON CHIP
Turntable Strobe Disc

Parts List – Precision Turntable Driver

1 PCB available from the *EPE PCB Service*, coded 04104161, 84.5 x 112mm
1 panel label 158 x 95mm (download from: **epemag.com**)
1 diecast box 171 x 121 x 55
1 20VA mains transformer 50/60Hz 2 x 115VAC, 2 x 9VAC
1 transformer terminal shroud
1 250VAC mains panel socket, flush-mounting
1 15VDC 2A supply (preferably a linear supply) or plugpack (or 12VDC with reduced output) or suitable 12V battery
1 DC socket, PC mount with 2.1 or 2.5mm centre pin to suit plugpack or supply lead DC plug
3 SPST micro switches (~3-4mm actuator) [for internal mounting] (S1-S3) ***OR***
3 SPST momentary contact switches [for on-lid mounting]
1 SPDT PCB-mount toggle switch
1 2-pin header with jumper shunt
1 20MHz 50ppm (or less) crystal (X1)
1 M205 2A slow blow fuse (F1)
2 M205 PCB mount fuse clips
1 18-pin IC socket
4 rubber feet
2 M3 tapped x 9mm spacers
2 M4 nuts
2 M4 x 10mm machine screws (countersunk or pan head)
2 M3 x 6mm machine screws (countersunk or pan head)
2 M3 x 6mm machine screws
5 M3 x 10mm machine screws
5 M3 nuts
1 star washer for M3 screw
1 large solder lug
4 TO-220 insulating bushes
4 TO-220 silicone washers
1 20mm diameter x 50mm heatshrink tubing
1 20mm length of green or green/yellow 7.5A mains rated wire
1 500mm length of brown 7.5A mains rated wire
1 100mm length of blue 7.5A mains rated wire
4 100mm cable ties

Semiconductors
1 PIC16F88-I/P microcontroller programmed with 0410416A.HEX (IC1)
1 LMC6484AIN quad rail-to-rail op amp (IC2)
1 LMC6482AIN dual rail-to-rail op amp (IC3)
1 7805 5V regulator (REG1)
2 IRF9540 P-channel MOSFETs (Q1,Q3)
2 IRF540 N-channel MOSFETs (Q2,Q4)
2 BC337 NPN transistors (Q5,Q7)
2 BC327 PNP transistors (Q6,Q8)
1 3mm red LED (LED1)
1 15V 1W zener diode (ZD1)
1 1N5404 3A diode (D1)
1 1N4004 1A diode (D2)
4 1N4148 diodes (D3 - D6)

Capacitors
1 4700µF 16V low ESR electrolytic
5 10µF 16V electrolytic
1 470nF 275VAC X2 class MKP (polypropylene) for 230VAC output
(1 x 2.2µF X2 class polypropylene for 115VAC output)
3 100nF MKT polyester
3 33nF MKT polyester
1 15nF MKT polyester
2 1.5nF MKT polyester
1 3.3nF MKT polyester
1 1nF MKT polyester
1 680pF ceramic
2 33pF ceramic

Resistors (1%, 0.5W; # = metal film)
6 150kΩ# 1 120kΩ 2 100kΩ 5 75kΩ# 3 22kΩ
9 10kΩ 1 2.2kΩ 6 1kΩ 2 100Ω 1 10Ω
1 20kΩ miniature horizontal mount trimpot (VR1)

Reproduced by arrangement with
SILICON CHIP magazine 2017.
www.siliconchip.com.au

Ideally, the unit should be powered with a linear 15V DC 2A supply rather than a switchmode type. A linear supply is one where the mains voltage is stepped down using a 50Hz transformer, rectified, filtered and regulated to 15V. This type of supply will avoid the injection of switching hash into sensitive magnetic cartridge signal leads.

Insert the slow-blow 2A fuse and apply power. Check that the voltage between pins 5 and 14 of the IC1 socket is close to 5V. Anywhere between 4.85 and 5.15V is OK. Switch off power and wait for the voltage on the IC socket to drop to below 1V and insert the programmed PIC16F88 into the socket, taking care to orient it correctly.

Trimpot VR1 needs to be adjusted to give the maximum undistorted sinewave output. The ideal way to do this is to use an oscilloscope to monitor the waveform.

If you do not have access to a scope and assuming that the DC supply is 15V, adjust trimpot VR1 to deliver 10.2V AC across the primary windings of the transformer.

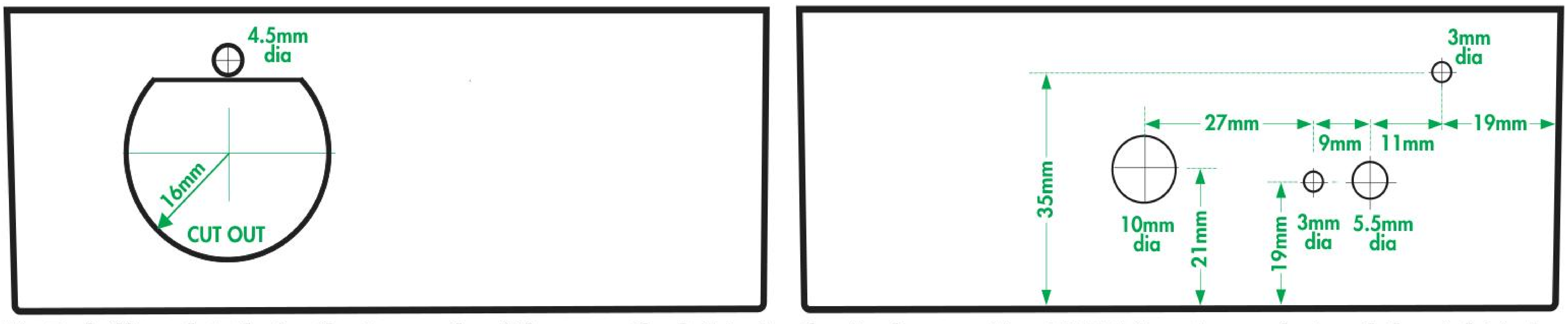


Fig.5: drilling details for the two ends of the case; the left is for the flush-mounting 250VAC mains socket and the right is for the switch, LED and DC socket. Additional holes will need to be drilled in the lid to accommodate the three speed switches.

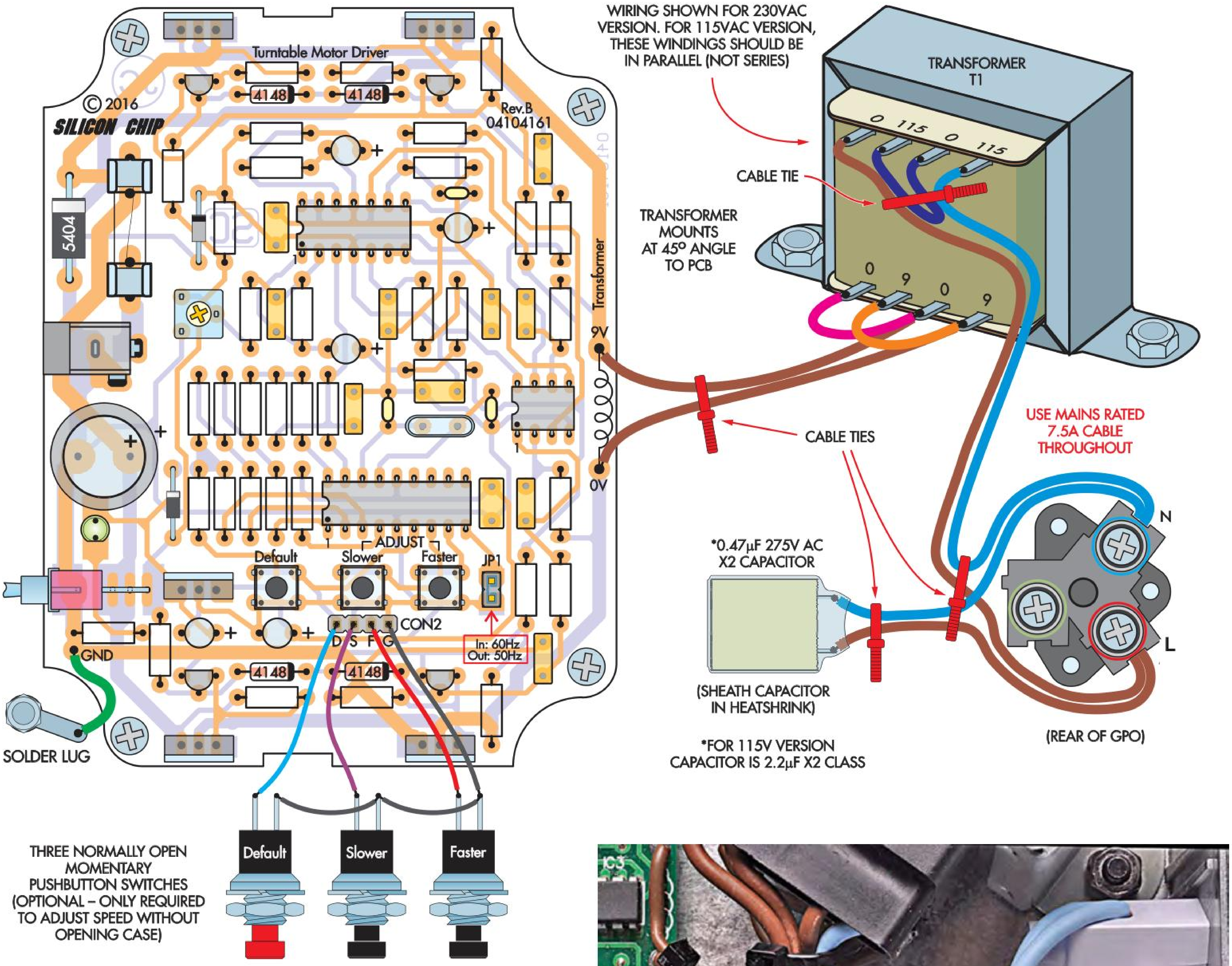
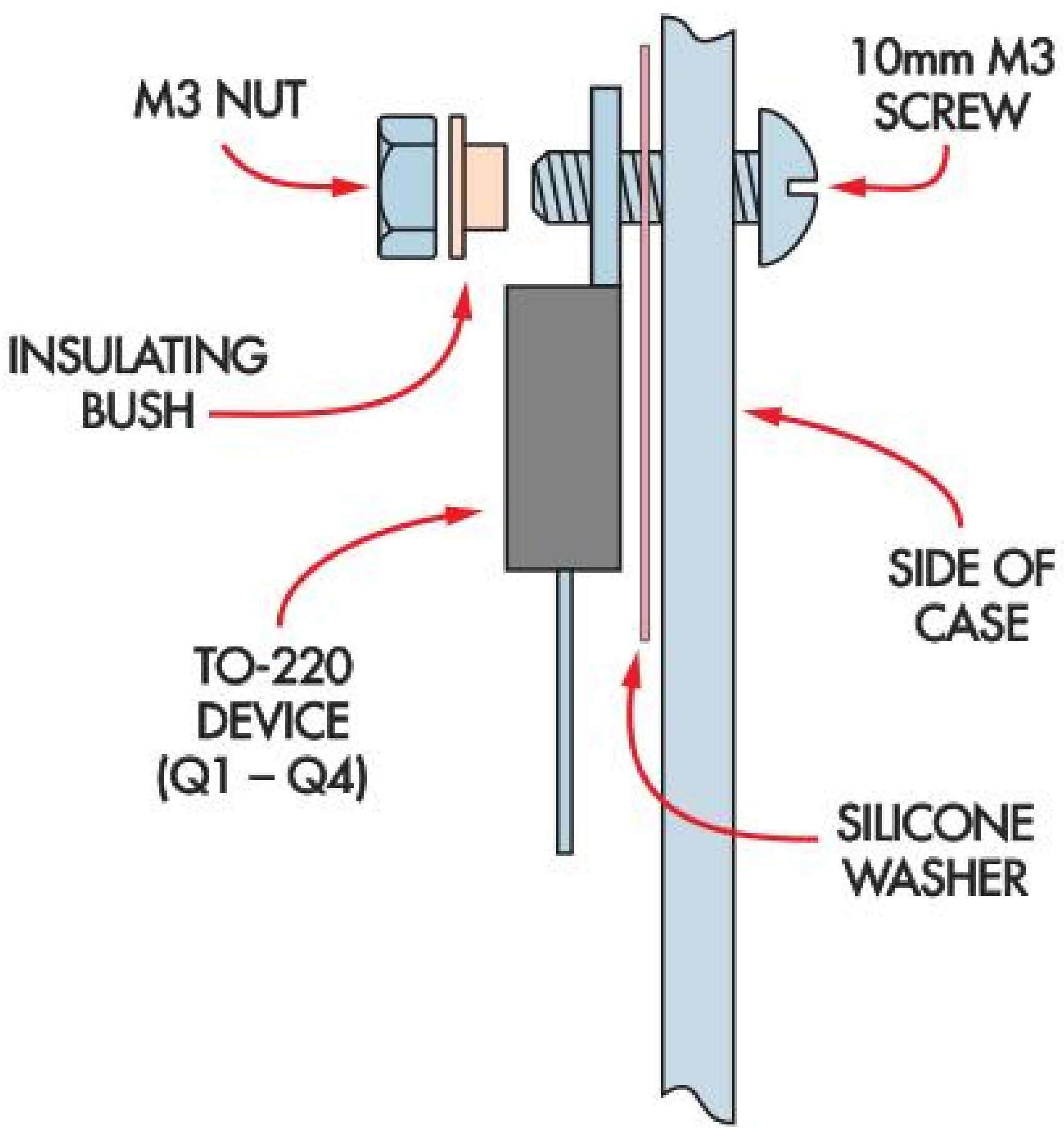
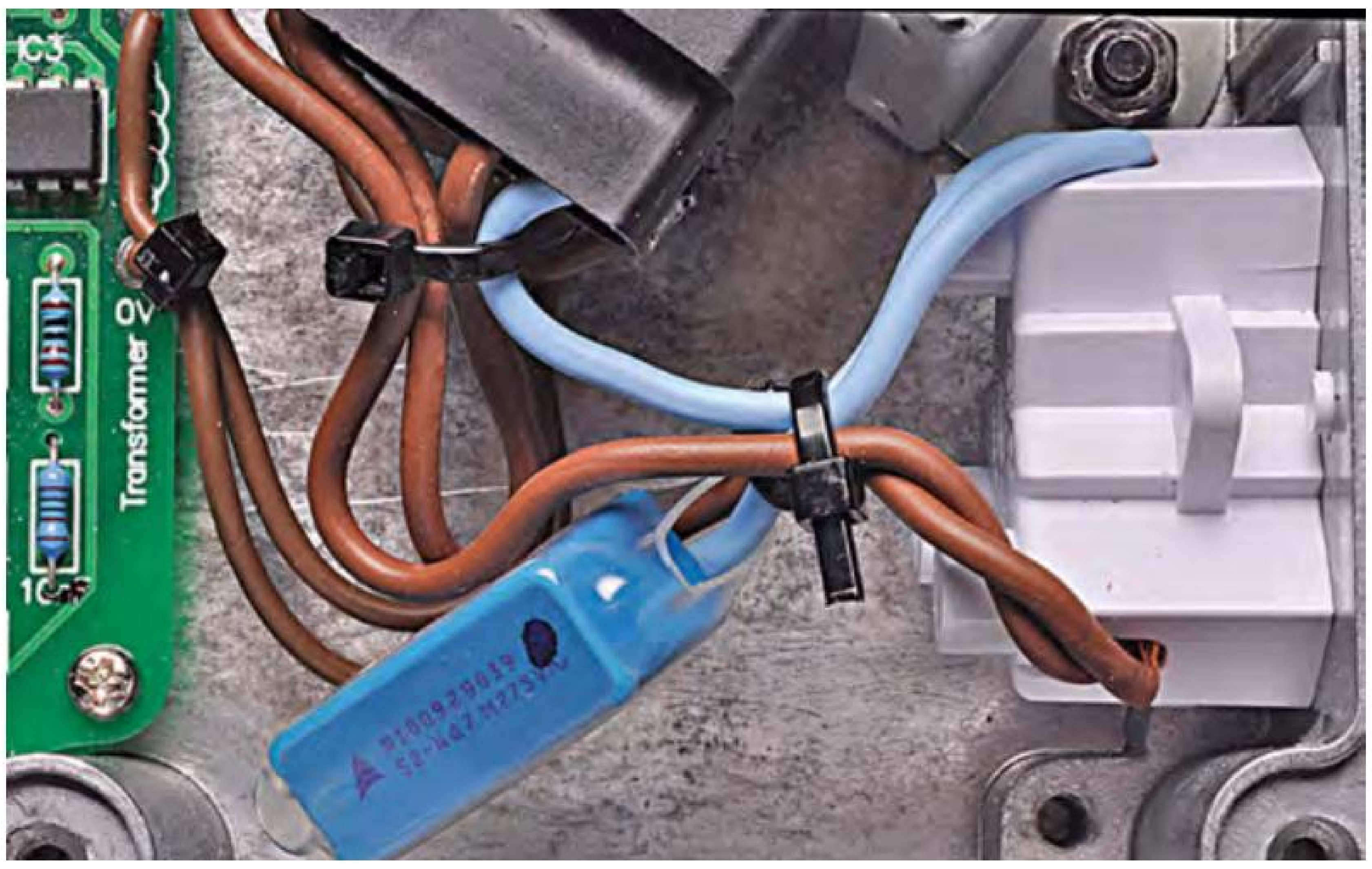

Turntable Motor Driver
© 2016
SILICON CHIP
Rev.B
04104161
4148
5404
Transformer
9V
0V
+
ADJUST
Default
Slower
Faster
JP1
CON2
D S F G
In: 60Hz
Out: 50Hz
GND
SOLDER LUG
WIRING SHOWN FOR 230VAC VERSION. FOR 115VAC VERSION, THESE WINDINGS SHOULD BE IN PARALLEL (NOT SERIES)
TRANSFORMER T1
0 115 0 115
0 9 0 9
CABLE TIE
TRANSFORMER MOUNTS AT 45° ANGLE TO PCB
CABLE TIES
USE MAINS RATED 7.5A CABLE THROUGHOUT
N
L
*0.47µF 275V AC X2 CAPACITOR
(SHEATH CAPACITOR IN HEATSHRINK)
*FOR 115V VERSION CAPACITOR IS 2.2µF X2 CLASS
(REAR OF GPO)
THREE NORMALLY OPEN MOMENTARY PUSHBUTTON SWITCHES (OPTIONAL – ONLY REQUIRED TO ADJUST SPEED WITHOUT OPENING CASE)
Default
Slower
Faster

Fig.6 (above) shows the wiring required for the unit, while Fig.7 (right) shows the mounting of the four MOSFETs. After mounting, check with a multimeter (on low-ohms range) to ensure the tabs are isolated.


M3 NUT
10mm M3 SCREW
INSULATING BUSH
SIDE OF CASE
TO-220 DEVICE (Q1 – Q4)
SILICONE WASHER



Here's a close-up of the mains output socket (GPO), connections to the transformer and to the capacitor across the transformer secondary. This must be sheathed in heatshrink, as shown.

If you are using a 12V battery, adjust trimpot VR1 to deliver 8.2V to the transformer primary.

When connecting up the turntable to the *Precision Turntable Driver* use the normal practice of connecting the turntable earth wire back to the amplifier earth terminal to minimise hum and noise. The case of the *Precision Turntable Driver* does not need to be connected to mains Earth.

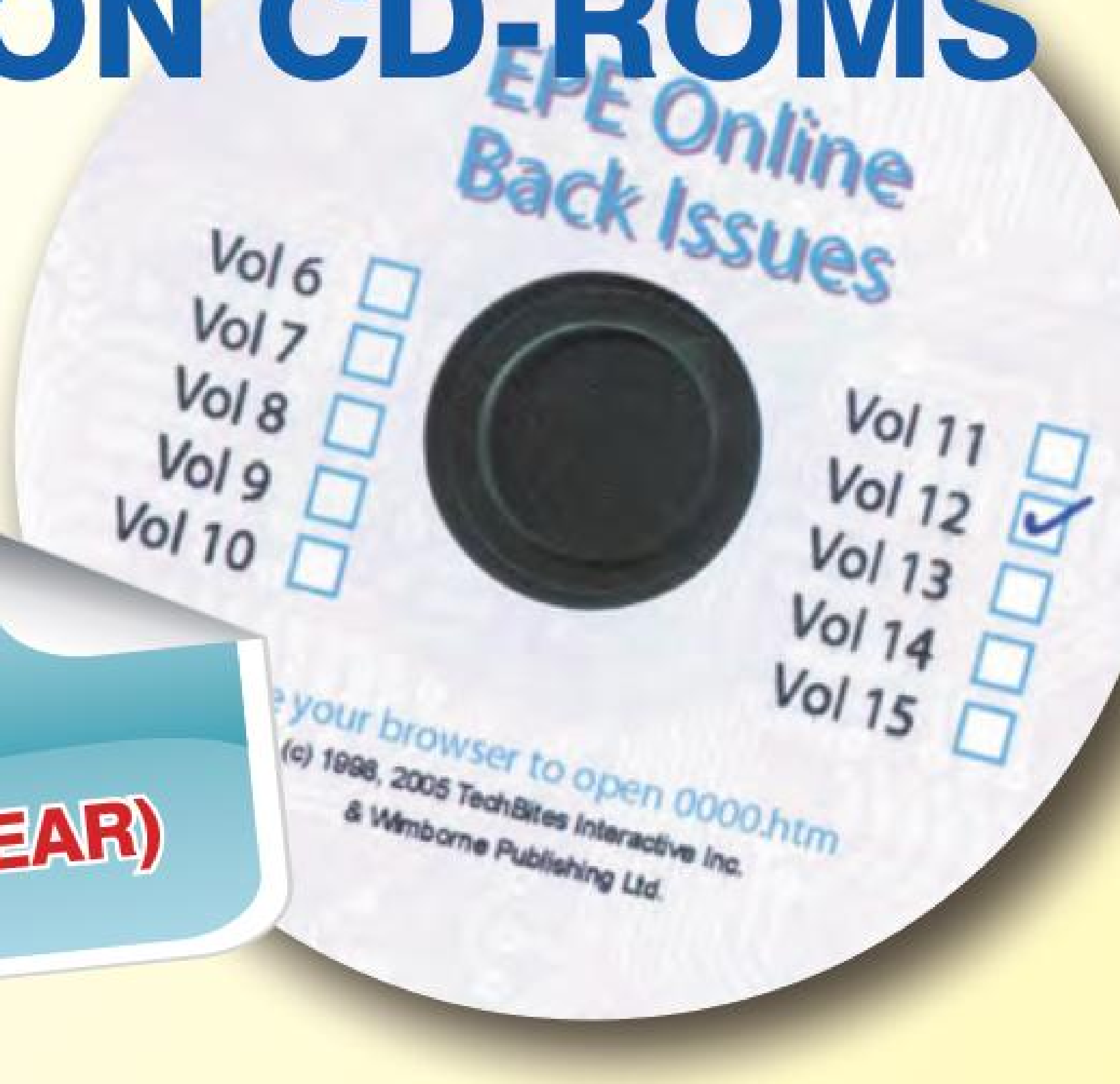
Setting the turntable speed

You can adjust the turntable speed using the faster or slower switches. For an exact speed setting, you will need to monitor the turntable speed using the *Turntable Strobe* and a strobe disc (see the article published in February 2017 entitled *Check Turntable Speed With This White LED Strobe*). Adjust the speed so the strobe markings appear stationary.

Note that, depending on the power rating of the turntable, the DC input voltage and the ambient temperature, the case of the *Precision Turntable Driver* will become warm after a few hours use. This is normal and to be expected since the drive circuitry is linear and its efficiency is only about 50%.

STORE YOUR BACK ISSUES ON CD-ROMS

Order on-line from
www.epemag.com (go to the UK store)
or by phone, fax, email or post


EPE Online
Back Issues
Vol 6
Vol 7
Vol 8
Vol 9
Vol 10
Vol 11
Vol 12
Vol 13
Vol 14
Vol 15
your browser to open 0000.htm
(c) 1998, 2005 TechBites Interactive Inc.
& Wimborne Publishing Ltd.

ONLY
£16.45
(£29.95 FOR 5 YEAR)
each including VAT and p&p

VOL 1: BACK ISSUES – January 1999 to June 1999
Plus some bonus material from Nov and Dec 1998
VOL 2: BACK ISSUES – July 1999 to December 1999
VOL 3: BACK ISSUES – January 2000 to June 2000
VOL 4: BACK ISSUES – July 2000 to December 2000
VOL 5: BACK ISSUES – January 2001 to June 2001
VOL 6: BACK ISSUES – July 2001 to December 2001
VOL 7: BACK ISSUES – January 2002 to June 2002
VOL 8: BACK ISSUES – July 2002 to December 2002
VOL 9: BACK ISSUES – January 2003 to June 2003
VOL 10: BACK ISSUES – July 2003 to December 2003
VOL 11: BACK ISSUES – January 2004 to June 2004
VOL 12: BACK ISSUES – July 2004 to December 2004
VOL 13: BACK ISSUES – January 2005 to June 2005
VOL 14: BACK ISSUES – July 2005 to December 2005
VOL 15: BACK ISSUES – January 2006 to June 2006
VOL 16: BACK ISSUES – July 2006 to December 2006
VOL 17: BACK ISSUES – January 2007 to June 2007
VOL 18: BACK ISSUES – July 2007 to December 2007
VOL 19: BACK ISSUES – January 2008 to June 2008
VOL 20: BACK ISSUES – July 2008 to December 2008
VOL 21: BACK ISSUES – January 2009 to June 2009
VOL 22: BACK ISSUES – July 2009 to December 2009
VOL 23: BACK ISSUES – January 2010 to June 2010
VOL 24: BACK ISSUES – July 2010 to December 2010
VOL 25: BACK ISSUES – January 2011 to June 2011
VOL 26: BACK ISSUES – July 2011 to December 2011
VOL 27: BACK ISSUES – January 2012 to June 2012
VOL 28: BACK ISSUES – July 2012 to December 2012
VOL 29: BACK ISSUES – January 2013 to June 2013
VOL 30: BACK ISSUES – July 2013 to December 2013
VOL 31: BACK ISSUES – January 2014 to June 2014
VOL 32: BACK ISSUES – July 2014 to December 2014
VOL 33: BACK ISSUES – January 2015 to June 2015

NEW
Vol.34

VOL 34: BACK ISSUES –
July 2015 to December 2015

FIVE YEAR
DVD/CD-ROMs
NOW AVAILABLE

FIVE YEAR CD/DVD-ROMs

No.1 – Jan '03 to Dec '07
No.2 – Jan '04 to Dec '08
No.3 – Jan '05 to Dec '09
No.4 – Jan '06 to Dec '10
No.5 – Jan '07 to Dec '11
No.6 – Jan '08 to Dec '12
No.7 – Jan '09 to Dec '13
No.8 – Jan '10 to Dec '14
No.9 – Jan '11 to Dec '15

NEW
No.9

NOTE: These DVD/CD-ROMs are suitable for use on any PC with a DVD/CD-ROM drive. They require Adobe Acrobat Reader (available free from the Internet – **www.adobe.com/acrobat**)

WHAT IS INCLUDED

All volumes include the *EPE Online* content of every listed issue. **Please note that we are unable to answer technical queries or provide data on articles that are more than five years old. Please also ensure that all components are still available before commencing construction of a project from a back issue.**

BACK ISSUES DVD/CD-ROM ORDER FORM

Please send me the following Back Issue DVD/CD-ROMs.

Volume Numbers:. . . . .
. . . .

Price £16.45 each, £29.95 for Five Year DVD/CD-ROMs – includes postage to anywhere in the world.

Name . . . .
. . . .
Address . . . .
. . . .
. . . .
Post Code. . . . .
☐ I enclose cheque/P.O./bank draft to the value of £ . . . .
☐ please charge my Visa/Mastercard £ . . . .
Card No. . . . .
Card Security Code . . . . (The last 3 digits on or just under the signature strip)
Valid From . . . . Expiry Date . . . .

SEND TO: **Everyday Practical Electronics,**
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU.

Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.
Normally posted within seven days of receipt of order.

NET WORK

by Alan Winstanley

Wireless printing

I'M THE sort who doesn't discard older technology without good reason, and any updates or upgrades must bring worthwhile benefits to make the swap a rewarding one. Here in my worklab my HP OfficeJet All-in-One was showing its age, so I hit the shops looking for a replacement. After studying the specs closely I chose an Epson XP-830 copier, printer, scanner and fax – a unit brimming with network features but which, like most such modern devices, has a clattery semi-disposable construction that makes you wonder if something might snap off in your hands. It's good enough for home and SOHO use though, provided it's treated sympathetically.

You get a lot of technology for £150 these days, and network-compatibility (both Ethernet and Wi-Fi) comes as standard in the Epson. Without me reading the manual the Epson XP-830 soon found its way onto my network, and it was simple to scan, copy and print, create PDFs and JPEGs or print colour photos from a memory card. As a standalone unit I found it copies, prints and scans to my PC over Wi-Fi with no problems at all, and the feeling of being released from a PC's USB port was quite a liberating one. Unusually, this Epson unit also has legacy support for Pictbridge cameras, both wireless and USB, so I can hook a digicam docking station or SLR to it and print high quality photos that way; Pictbridge works seamlessly. The design is rounded off with very good paper handling, duplex printing and a large LCD touchscreen. Epson also gives the printer its own email address, allowing images to be mailed through the cloud and you can print from a mobile phone as well. A standalone and PC-based fax client are also included – yes, I still have to fax documents sometimes – and the five separate ink tanks can obviously be replaced individually. Overall, it demonstrates how far this kind of peripheral has now come, and I'm looking forward to having a more productive workflow thanks to the Epson's network capabilities.

Not so Eudorable?

In March's issue I mentioned an offline email program (Eudora) that I still use to handle my email correspondence, admittedly swimming against the tide of subscription-based software or free online mail services. My thanks to reader Andrew Coward who wrote: 'I enjoyed reading your article in the March 2017 issue but, as an IT professional, I feel that suggesting people use unsupported, out-of-date software is irresponsible. There may well be people out there still targeting unpatched vulnerabilities, and email security is very important in the age of Internet banking. If you want to use a non-commercial email client then Thunderbird is probably the spiritual successor to Eudora (Qualcomm used to contribute code to the Mozilla foundation). Or a quick search for "open-source email client" will return viable alternatives.'

Epson's XP-830 All-in-One is typical of the latest generation of network printer-scanners suitable for the home user. Wi-Fi, Ethernet, USB, fax, duplex printing and Pictbridge are just some of its features

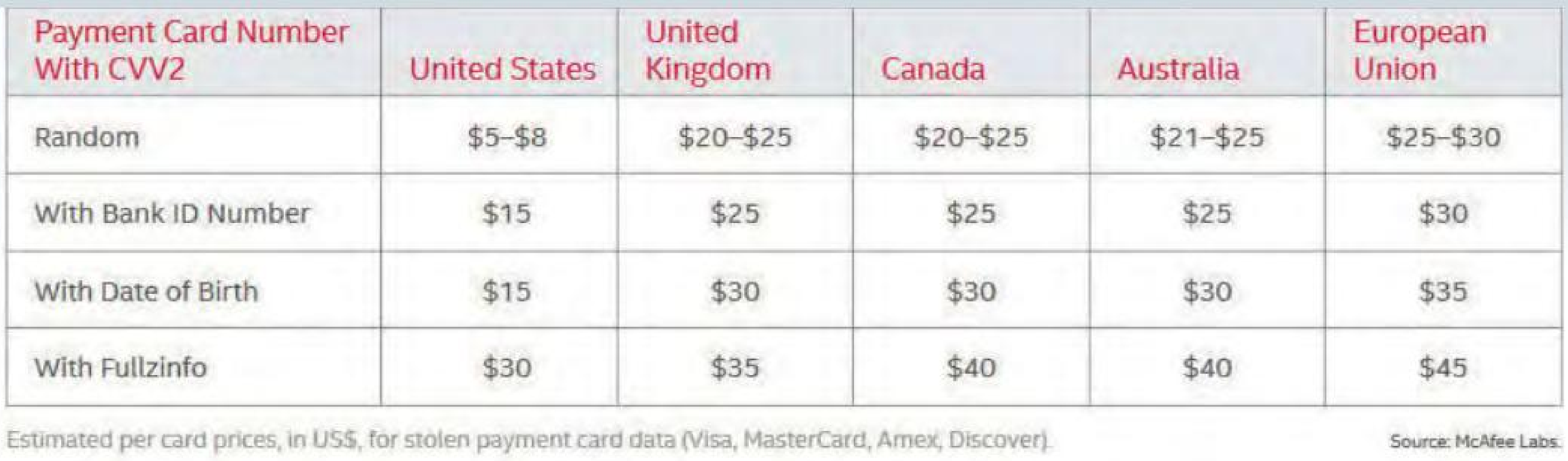
I concede that the sun is setting on Eudora, along with the whole traditional way of running PC software. I suggested Eudora for enthusiast power PC users, not for novices or everyday users, mainly because in my view it's a bit tricky to coax the program into operation rather than being inherently insecure. In fact, Eudora still enjoys a decent-sized userbase today, but of course this legacy software will never be updated.

As mail protocols change then Eudora may become incompatible or vulnerable to the point that it's no longer rewarding to use. Of course I can't rule out someone figuring out how to hack a Eudora .mbx file for example, or creating some sort of 'man in the middle' exploit that steers Eudora towards fetching mail from a rogue server. As far as I know, no CVEs (Common Vulnerabilities and Exposures) are noted for Eudora V7.x, which doesn't mean that none exist, but global tech companies such as Adobe and LinkedIn have suffered major hacks and data theft in the past, and on balance I think hackers have much bigger fish to fry than trying to exploit an obscure program like Eudora. I suppose it's because Eudora is so 'off the radar' that it's been left alone for so long. As for handling phishing or virus emails, Eudora is as prone to that as other offline mail programs.

I've mentioned other offline email clients in the past, including Thunderbird, which Andrew suggested, also RitLabs The Bat! and emClient (*Net Work*, Jan 2016), but I found none matched the power and flexibility of Eudora's filtering and search, and personally I didn't see them as being any more secure. Otherwise, there is increasingly less choice other than to opt for online webmail or a subscription-based service like Office 365.

Credit where it's due

Decades ago, in the pre-Internet era, I signed up to a credit-card protection scheme that saw me filling in tiny little slips of paper with my store and credit card numbers and, with fingers crossed, posting them off somewhere. Any lost credit cards or key fobs could then be returned home, or I could alert the agency of credit card loss, so that 'stops' could be put on my cards. Looking back, it was a very clumsy process, but this was an era when signed credit-card slips were just thrown away instead of being destroyed securely and credit fraud was already becoming rife.



Payment Card Number With CVV2	United States	United Kingdom	Canada	Australia	European Union
Random	\$5–\$8	\$20–\$25	\$20–\$25	\$21–\$25	\$25–\$30
With Bank ID Number	\$15	\$25	\$25	\$25	\$30
With Date of Birth	\$15	\$30	\$30	\$30	\$35
With Fullzinfo	\$30	\$35	\$40	\$40	\$45

Estimated per card prices, in US\$, for stolen payment card data (Visa, MasterCard, Amex, Discover). Source: McAfee Labs.

What stolen credit card data is worth on the criminal market, from McAfee's The Hidden Economy *(2015)*

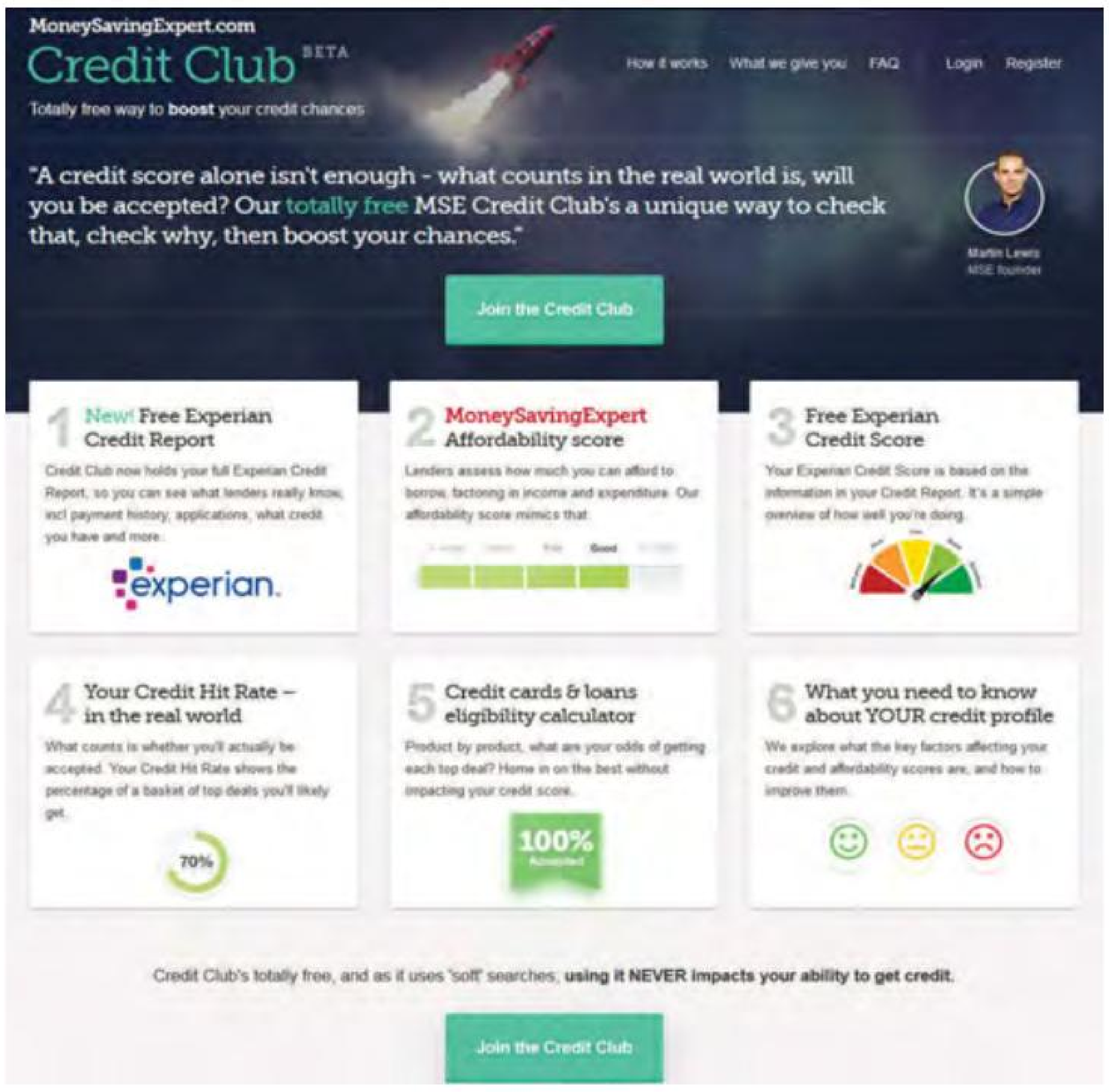
Card Protection Plan (CPP) was a major provider and their little update forms nestled for years in a drawer next to my chequebook. As they say in the trade, 'insurance is never bought, it is sold', and CPP in the UK was subsequently hit by a mis-selling scandal involving credit card and ID theft protection schemes. As a consequence, they were clouted with a £1.3bn compensation scheme. (See the full story at: **www.moneysavingexpert.com/reclaim/CPP-card-protection**). Today, a much-slimmed-down CPP operation in Britain has re-invented itself, still offering 'Card Rescue', which might suit some applicants, but they will dissuade you from joining if you only have a card or two because – as they readily admit – you could easily cancel any lost cards yourself.

In the past, *Net Work* has reported how scraps of individual financial or personal details could be stolen and re-assembled on the dark side of the web, where crooks gradually build up your profile for sale to fraudsters and villains. An eye-opening report about this was published in 2015 by security firm McAfee entitled *The Hidden Data Economy*, which you can read at: **http://tinyurl.com/zcj6hsj**. Included were estimates of the criminal resale price of stolen credit card data.

CPP Group has now launched a new online service intended to alert consumers of possible data theft, also aiming to mitigate the risks caused by personal data falling into the wrong hands. Its latest venture is OwlDetect, which it claims monitors the dark side of the web 24-7 and alerts you if your details suddenly pop up 'in the wrong place'. They also offer to run your details through a database that holds a decade's worth of data retrieved from unlawful or shady websites. If any hits are flagged up then CPP promises to notify you and help you create an action plan to limit any potential damage. Credit cards, bank accounts, passport and NI numbers can be covered and their website offers logins for both UK and German customers. Consumers will doubtless weigh up the risks for themselves, but if the idea appeals to you then Owldetect charges £3.50 per month for their new monitoring service. More details at: **owldetect.com**. Readers can also check if their email address might have been stolen ('pwned') in some widely publicised data breaches by visiting: **https://haveibeenpwned.com** and you can sign up for free alerts as well.

Until fairly recently, Britain's consumer credit referencing systems were pretty much a hazy closed-shop dominated by a handful of credit references agencies. It is only now that British consumers have woken up to this and are taking more responsibility for managing their credit files. The two main agencies, Experian and Equifax, strive to sell a full credit monitoring service for a monthly fee. However, some new basic free services available online have now skewed the market in our favour: Call Credit's Noddle (**www.noddle.co.uk**) broke the mould by offering a free service for consumers for the first time, followed by Clearscore.com, Experian CreditMatcher and more recently, MoneySavingExpert's Credit Club. You can sign up online and view your basic reports yourself without attracting attention (desirable because too many 'official' credit searches would give an impression that you're desperately applying for finance).

Just like Owldetect, major credit reference agencies strive to extract a regular subscription from you by offering to alert you about any fraudulent-looking activity that's possibly caused by ID theft. They can also suggest finance deals tailored towards your credit rating. This helps you avoid impacting your credit file with loan rejections from unsuitable lenders. My personal choice is Noddle, which showed me how a simple online application for car insurance triggered a blizzard of 'official' searches, all of which were recorded in the credit file; that's one way insurers know you have been shopping around. It's useful to know what the credit reference industry knows about you, so it's worth periodically logging in to Noddle or similar sites to see the picture for yourself.



Totally free way to **boost** your credit chances

"A credit score alone isn't enough - what counts in the real world is, will you be accepted? Our totally free MSE Credit Club's a unique way to check that, check why, then boost your chances."

Martin Lewis
MSE founder

1 New! Free Experian Credit Report

Credit Club now holds your full Experian Credit Report, so you can see what lenders really know, incl payment history, applications, what credit you have and more.

2 MoneySavingExpert Affordability score

Lenders assess how much you can afford to borrow, factoring in income and expenditure. Our affordability score mimics that.

3 Free Experian Credit Score

Your Experian Credit Score is based on the information in your Credit Report. It's a simple overview of how well you're doing.

4 Your Credit Hit Rate – in the real world

What counts is whether you'll actually be accepted. Your Credit Hit Rate shows the percentage of a basket of top deals you'll likely get.

5 Credit cards & loans eligibility calculator

Product by product, what are your odds of getting each top deal? Home in on the best without impacting your credit score.

6 What you need to know about YOUR credit profile

We explore what the key factors affecting your credit and affordability scores are, and how to improve them.

Credit Club's totally free, and as it uses 'soft' searches, **using it NEVER impacts your ability to get credit.**

MoneySavingExpert's Credit Club is the latest to offer UK consumers free online credit reference checking

amazon
amazon

The updated Fire TV Stick has a microphone button on the wireless remote

Amazon gets more Stick

Last month, I explained that I had succumbed to buying Amazon's Fire TV Stick, an HDMI dongle that converts an ordinary TV or monitor into a smart TV capable of offering catch-up TV, Netflix, YouTube, apps and more besides. It includes a 5V USB supply and a small wireless remote control that works surprisingly well. Not one to rest on its substantial laurels, Amazon has announced a new version that will feature Alexa Voice Remote, Amazon's voluble voice assistant that will give users the power to use voice recognition commands to search and control their Fire TV Stick.

Alexa will help you with tasks and manage a smart home by controlling smart appliances, in the same way that an Amazon Echo does. The dongle's price has edged up and UK buyers can pre-order for £39.99 from: **www.amazon.co.uk/firetvstick**. Shipping commences on 6 April. Users of the Raspberry Pi can add Alexa Voice Service (AVS) to a Pi to utilise Amazon's voice-recognition interface themselves (see *Net Work*, February 2017 issue).

That's all for this month's *Net Work*. You can contact the author at: **alan@epemag.net** or send comments for possible inclusion in *Read Out* to: **editorial@wimborne.co.uk**

EPE product review

Smith And Larson Audio
Thiele Small Testing
Win98se
WinMe
Win2K
WinXP
Version 2
Woofer Tester 2
Smith and Larson Audio
Woofer Tester 2
www.woofertester.com
SPEAKER STATUS
LINE OUT

Smith & Larson Audio

Woofer Tester 2

by Julian Edgar

Find speaker specs in minutes! Directly measure Thiele Small speaker specifications, and design effective speaker enclosures for drivers that don't normally have proper specs available.

If you're into sound systems, you'll be well aware of the famed Thiele Small speaker parameters that are especially important when designing woofers and subwoofers. These parameters are the speaker specs that you plug into software (or an on-line calculator) to allow you to design the speaker box. That box design includes aspects such as internal volume and length, and the diameter of any ports.

Without the Thiele Small (abbreviated to TS) specs of the driver, you're just guessing the box design – and the chances are overwhelming that your guess will be less than optimal.

So to design a good speaker enclosure, the TS specs are needed. That's fine if you're buying a new driver. But what if you've sourced a speaker that is literally an unknown? – for example, a second-hand driver? In that case, to get best results, the driver's Thiele Small specs need to be measured.

Woofer Tester 2

Woofer Tester 2 is a complete speaker test unit. This incredible piece of hardware plugs into the USB port of a PC or laptop and connects straight to the speaker under test. Open the software, press a button and within minutes many of the TS specs are measured. Do some more testing (eg, weighting the cone a known amount) and the rest of the important specs are there in front of you – it's that easy!

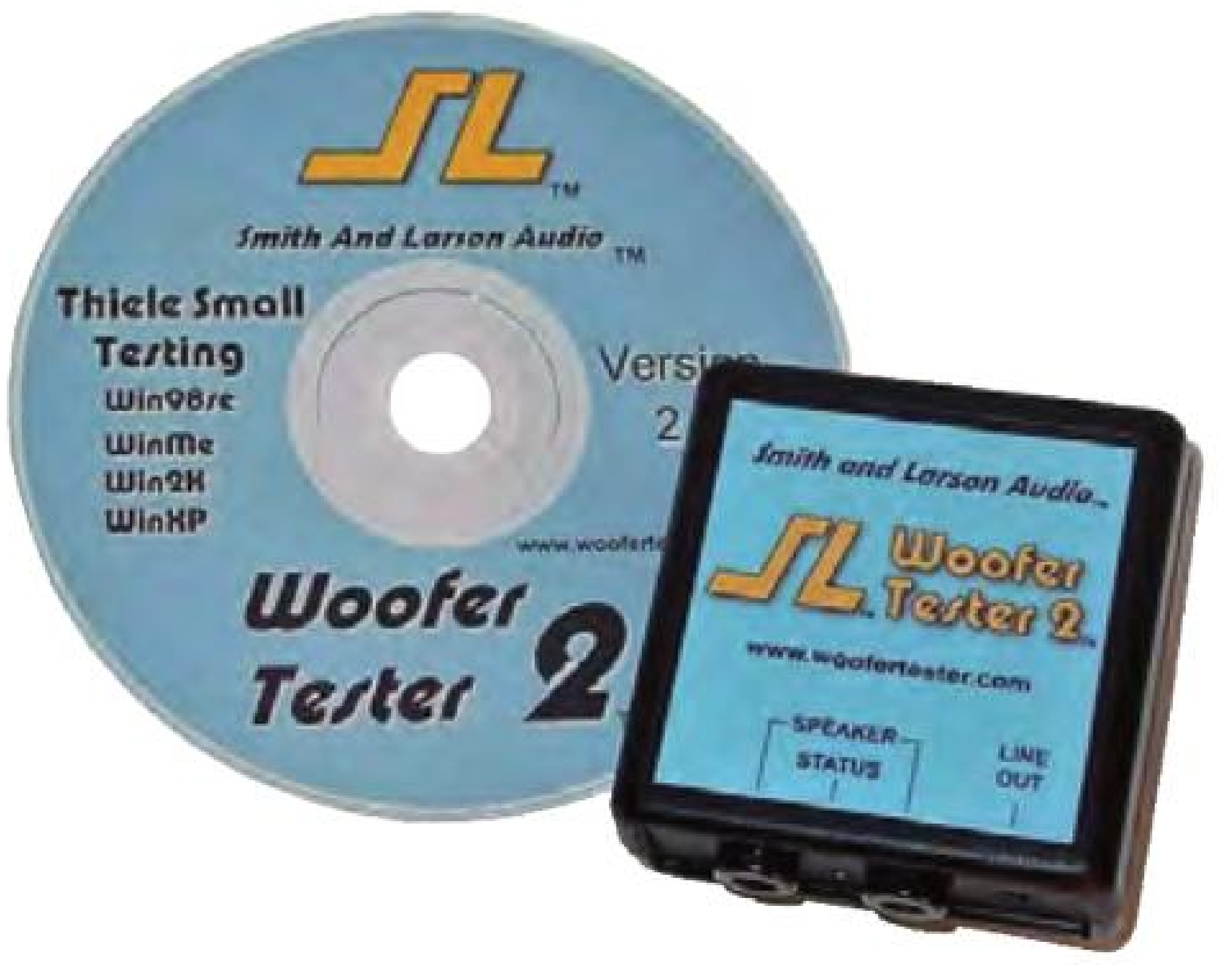


Fig.1. Woofer Tester 2 comprises a hardware and software solution for quickly and easily measuring the Thiele Small parameters of loudspeaker drivers. The software also allows you to design enclosures.

Furthermore, the Woofer Tester 2 also includes a box design tool so you can develop the enclosure without exiting the package.

Fig.2. Directly measuring Thiele Small parameters allows you to use high-quality drivers (like these Alpine car sound speakers) in custom-designed Hi-Fi enclosures.

And here's the cherry on the cake – once the box is built, you can use the Woofer Tester 2 to test the speaker mounted in its enclosure, seeing if the measured performance matches the prediction. (Woofer Tester does *not* include a microphone, so you cannot directly measure frequency response – but indirectly you can get a good idea of what is happening, for example through the impedance plot.)

At US$160, Woofer Tester 2 is not dirt cheap – but if you buy second-hand speakers, you need to use it only a few times to save that amount. (Of course, if you are using new drivers, you can also check to see if a manufacturer's specification for an individual speaker is correct – there is often some variation in the build from driver to driver.)

At its most complex, the Woofer Tester 2 has plenty of in-depth capability. But at its simplest (as we'll look at here), it's easy to get up and running.

Testing a driver

Woofer Tester 2 is used in the following manner. The software is installed and then the module calibrated using the provided test resistor. The provided alligator-clip leads are then used to connect the hardware to the speaker under test.

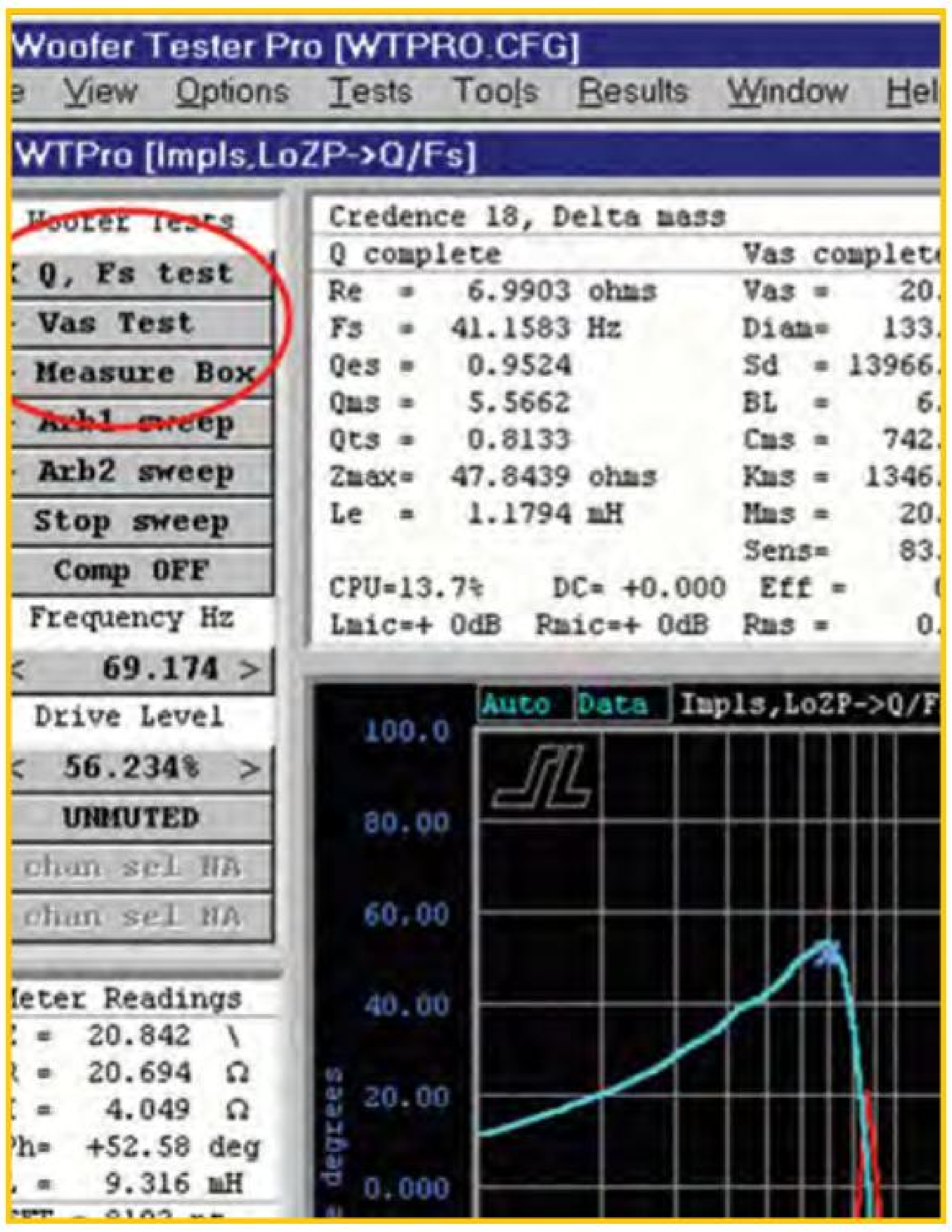
The speaker is placed on its back, ensuring that if it has a vented pole piece (ie vent hole in the magnet) this is not blocked.

In the software, the 'WT control' is opened from the View tab. The 'Q, Fs' test button is then pressed, and the speaker test starts automatically. The impedance (Re) of the speaker is measured and displayed, then the resonant frequency (Fs) and total Q (Qts) are ascertained. (Other factors are also measured, but I am trying to keep this simple.) This element of the test procedure takes a few minutes, during which you can watch the impedance plot for the speaker developing on the screen in front of you. So, for example, the measured specs of a good 5-inch woofer might be:

- Re = 5.35Ω
- Fs = 68.2Hz
- Qts = 0.48

The next step is to press the 'Vas' test button. A dialog box pops up that asks you to add a weight to the upwards-facing cone. I live in Australia, so I use two Australian $2 coins that have a mass of 6.6g each (a current UK 10p coin weighs 6.5g and is a little wider and thinner). The added weight is therefore 13.2g. The effective diameter of the speaker cone is also manually measured (callipers or a ruler) and then this figure is entered.

The compliance (Vas) is measured by the software, and the speaker sensitivity



```
Credence 18, Delta mass
Q complete                      Vas complete
Re   =   6.9903 ohms            Vas =    20.
Fs   =  41.1583 Hz              Diam=   133.
Qes  =   0.9524                 Sd  = 13966.
Qms  =   5.5662                 BL  =     6.
Qts  =   0.8133                 Cms =   742.
Zmax=   47.8439 ohms            Kms =  1346.
Le   =   1.1794 mH              Mms =    20.
                                Sens=    83.
CPU=13.7%      DC= +0.000      Eff =
Lmic=+ 0dB     Rmic=+ 0dB      Rms =     0.
```

```
Frequency Hz
<   69.174 >
Drive Level
<  56.234%  >
```

```
leter Readings
: =  20.842  \
. =  20.694  Ω
: =   4.049  Ω
h=  +52.58 deg
. =   9.316 mH
```

Fig.3. A variety of tests are available for ascertaining driver characteristics. Measuring specs such as Q, Fs and Vas are quickly and easily done.

calculated. This takes about another 30 seconds and adds to our spec list for the 5-inch woofer:

- Vas = 11.9 litres
- Sens = 90.1dB (at 1W, 1m)

Modelling enclosures

Now we model a suitable enclosure. Opening the 'T/S Simulation' from the View tab gives you the in-built Thiele Small speaker design software. The 'Test – Sim' button allows you to import into the simulator the results you just got from the speaker test. Opening the 'Overlay' allows you to graph the predicted results of your various enclosure designs. These graphs change in real time as you alter enclosure dimensions and port sizes. You can model vented, sealed, bandpass and passive radiator enclosure designs.

For example, using the tested specs described above for the 5-inch woofer, the software can be used to model an enclosure. In this case, a good result comes from using an eight-litre enclosure tuned to 57Hz using a port 25mm in internal diameter and 36.8mm long. The software can predict for this enclosure design the frequency response, impedance, phase – and lots of other parameters.

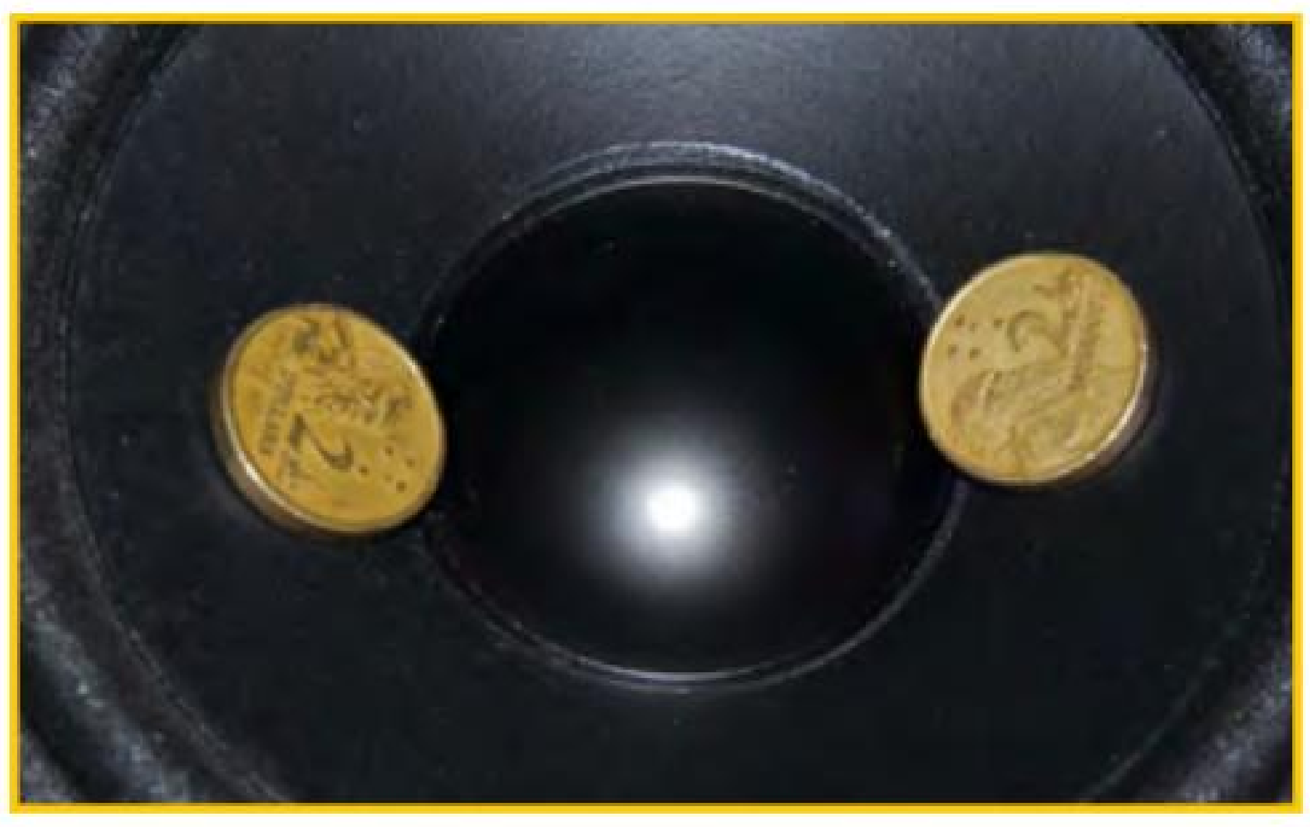


Fig.4. Small weights are added to the cone (here coins have been used). Software to calculate speaker compliance uses the resultant change in resonant frequency of the driver.

The next step is to build the suggested enclosure, then use the Woofer Tester 'Box test' function to test the completed speaker. You can then see how the tested box compares with the predicted performance, and make minor changes to the box design until the two line up perfectly.

Advantages and disadvantages

The enormous benefit of Woofer Tester 2 is that you can use it to measure the Thiele Small specs of drivers that are not provided with those specifications.

For example, few (if any) 4-inch, 5-inch and 6-inch speakers come with Thiele Small specifications. Thus, you have no real way of designing effective speaker enclosures for these small speakers.

As described earlier, you can also make excellent use of salvaged and second-hand speakers. Brand-name surround-sound home sound systems often have small, high quality drivers – but they're typically placed in poorly designed enclosures. Salvage some of these speakers, measure the driver's specs, model a good enclosure to suit, build the enclosure and then test it – and you can have quality sound at a fraction of the price you'd otherwise pay.

And the disadvantages?

At US$160, Woofer Tester 2 is a non-trivial purchase. However, if you share it with friends (each put in say $40) then it will pay for itself very quickly.

Another disadvantage is that you need to already have some knowledge of speaker specs like Fs, Vas and Qts, and to have previously used some enclosure modelling software. I think that with no knowledge at all in these areas, the learning curve will be too great. The provided handbook is OK (but not wonderful) and some of the software actions are not intuitive and are therefore a bit clunky.

Conclusion

If you are interested in speaker design, this package is quite unbelievable in what it can achieve, quickly and – once you get used to it – easily as well.

Measuring the specs for yourself

If you do a search online, you'll find plenty of DIY techniques for measuring TS parameters.

You'll need a precision resistor, an AC multimeter that measures over a wide frequency range, and a frequency generator. And a lot of time spent doing very finicky measurements and plugging numbers into equations.

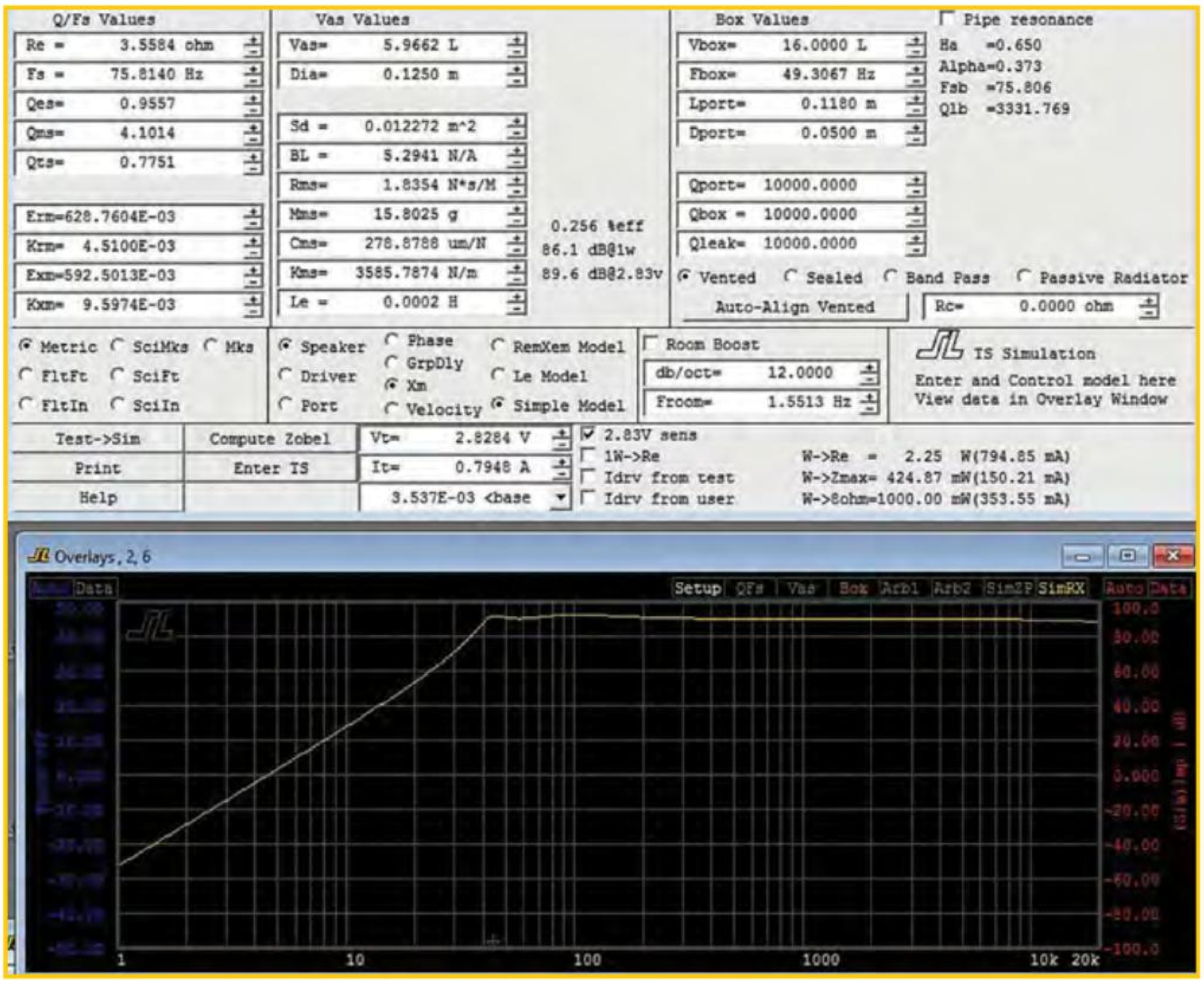
So it's certainly possible to do it manually – but it's time-consuming and likely to be not as accurate as using Woofer Tester 2.

Purchase

Woofer Tester 2 is available from Smith & Larson Audio in the US at: **www.woofertester.com**

Disclosure

The review author paid full price for the review copy.



```
Re =      3.5584 ohm      Vas=      5.9662 L           Vbox=     16.0000 L     ☐ Pipe resonance
Fs =     75.8140 Hz       Dia=      0.1250 m           Fbox=     49.3067 Hz    Ha    =0.650
Qes=      0.9557                                       Lport=     0.1180 m     Alpha=0.373
Qms=      4.1014          Sd =   0.012272 m^2          Dport=     0.0500 m     Fsb   =75.806
Qts=      0.7751          BL =      5.2941 N/A                                 Qlb   =3331.769
                          Rms=      1.8354 N*s/M       Qport=  10000.0000
Erm=628.7604E-03          Mms=     15.8025 g           Qbox =  10000.0000
Krm=  4.5100E-03          Cms=    278.8788 um/N        Qleak=  10000.0000
Exm=592.5013E-03          Kms=   3585.7874 N/m
Kxm=  9.5974E-03          Le =      0.0002 H

0.256 %eff
86.1 dB@1w
89.6 dB@2.83v

● Vented   ○ Sealed   ○ Band Pass   ○ Passive Radiator
Rc=     0.0000 ohm

● Metric  ○ SciMks  ○ Mks     ● Speaker  ○ Phase     ○ RemXem Model    ☐ Room Boost
○ FltFt   ○ SciFt             ○ Driver   ○ GrpDly    ○ Le Model        db/oct=     12.0000
○ FltIn   ○ SciIn             ○ Port     ● Xm        ● Simple Model    Froom=      1.5513 Hz
                                         ○ Velocity

Vt=       2.8284 V     ☑ 2.83V sens
It=       0.7948 A     ☐ 1W->Re             W->Re   =   2.25  W(794.85 mA)
3.537E-03 <base        ☐ Idrv from test     W->Zmax= 424.87 mW(150.21 mA)
                       ☐ Idrv from user     W->8ohm=1000.00 mW(353.55 mA)
```

Fig.5. Here a speaker driver has been measured and the data imported into the enclosure design program that has been used to develop a 16-litre ported enclosure. The predicted frequency response is shown on the graph.

INTERFACE

By Robert Penfold

micro:bit ins and outs

A PREVIOUS *Interface* article (*EPE*, January 2017) included a first look at the BBC micro:bit computer. Mike Tooley will be having a detailed look at this device from next month, but by way of a taster, in this month's column I am going to briefly revisit the device. This is not intended to be a complete guide to using and programming it – just an introduction to get you interested!

The micro:bit has built-in features that enable it to be used in many 'fun' ways, but is it usable for what might be considered more serious applications? Let's examine its general interfacing options – and possible shortcomings.

On the edge

The micro:bit version of a GPIO (general purpose input/output) port is provided by a connector along the bottom edge of the board, as shown in Fig.1. This provides 0V and 3V supplies, plus various input/output lines. The number of lines is rather limited in comparison to something like a Raspberry Pi, and most of the available lines are shared with on-board hardware such as the two pushbutton switches. This means that their use does have some limitations, and in some cases they are probably of no real use for simple interfacing purposes.

However, some lines are not used by the board's own hardware, and can be used freely with external circuits. These are the three large pins on the edge connector that are marked '0', '1', and '2', plus pins 8, 12, and 16. Here I am adhering to the micro:bit convention, and referring to the pads as 'pins'. There is 'reserved accessibility' for pin 12, which I presume means that it could be set aside for a specific function in the future. The prospects for simple parallel interfacing would seem to be limited by the small number of available input/output lines. On the other hand, pins 13 to 15 are provided for use with serial peripheral interfacing (SPI), while pins 19 and 20 are for I^2C interfacing. The interfacing potential is effectively unlimited when using these serial methods.

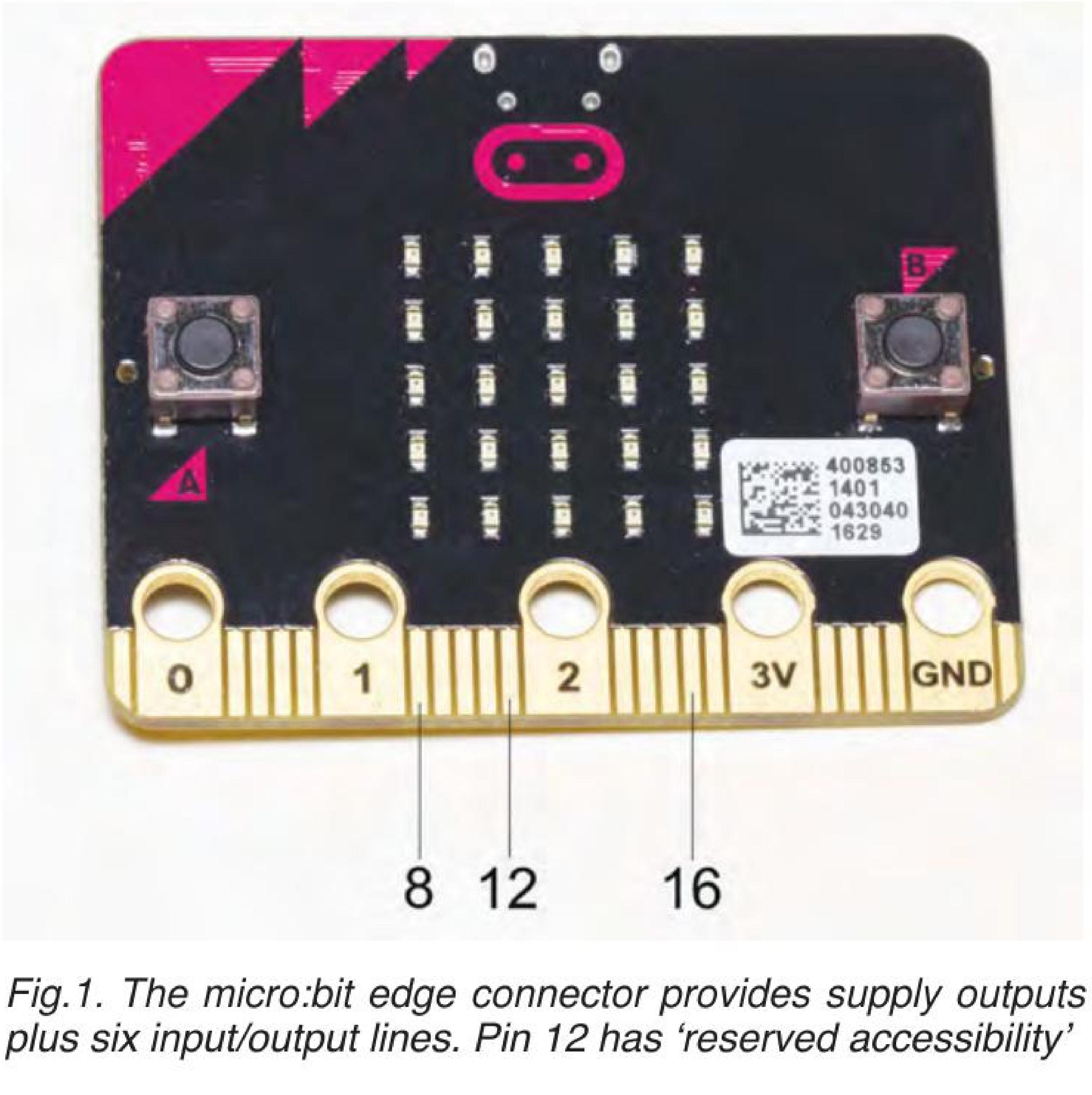


Fig.1. The micro:bit edge connector provides supply outputs plus six input/output lines. Pin 12 has 'reserved accessibility'

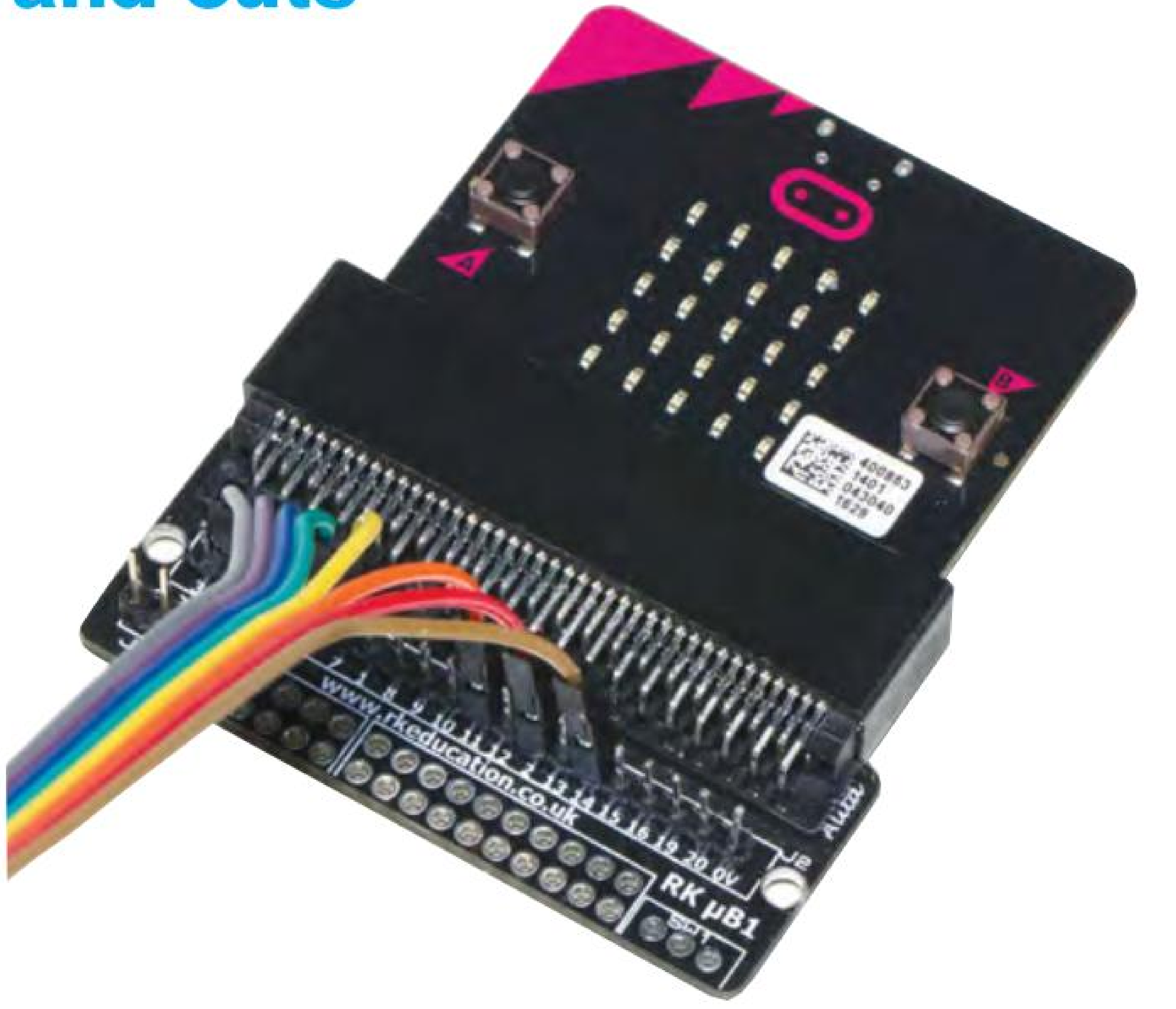


Fig.2. An adaptor is needed to provide proper access to the edge connector so that it can be connected to a solderless breadboard, or other prototyping system

Getting physical

From a physical point of view, interfacing to the large pins can be achieved using small crocodile clips. The micro:bit documentation suggests that 4mm banana plugs can also be used, but most modern connectors of this type are more complex than the twin-fingered plugs of yesteryear, and cannot be used in this way. A suitable edge connector is needed in order to use the smaller pins, and for anything other than some simple dabbling with the large pins. There are connector assemblies available that make it easy to use the micro:bit with solderless breadboards (Fig.2), or a home-made equivalent could be constructed.

From an electrical point of view, it has to be borne in mind that the micro:bit operates from a nominal 3V battery supply, or a 3.3V supply if it is powered from a USB port. When powered from a USB port I found that the supply voltage of my mico:bit was actually around 3.2V to 3.25V, and varied slightly depending on the number of active LEDs in the display. When powered from a battery the supply voltage could be anything from about 2.7V to 3.3V. Using power from a USB port, the logic levels are 3.3V types rather than the 3V variety. Using a battery supply they can be at one or the other, or anywhere in-between!

In practice, it is unlikely that there would be problems using the GPIO port with 3V or 3.3V logic circuits, but direct operation with 5V logic devices would be inadvisable. Apart from the risks of driving inputs with an excessive voltage, the differences in the two sets of logic levels could be too great to provide reliable operation. As with the Raspberry Pi, either the add-on circuit must operate at 3 or 3.3V logic levels, or suitable level-shifting buffers must be included on each GPIO line.

The GPIO lines do not have any true analogue output capabilities, but can use pulse-width modulation (PWM) to provide a controllable output voltage of sorts. Pins '0', '1' and '2' can act as analogue inputs with 10-bit resolution. This gives a range of 0 to 1023, which roughly equates to a 3½-digit display. It is certainly enough to give accurate results in a number of practical applications, and is the equal of many digital multimeters.

Up in the clouds

The normal way of programming a micro:bit is to use a cloud-based system. I cannot claim to be a fan of this approach, but here it has the big advantage of making things largely independent of the user's hardware and operating system. It does not matter whether you are using a Windows-based PC, a Mac, or a Raspberry Pi running Linux, it should be possible to write and compile micro:bit programs.

First, you go to the appropriate web page and select the required programming language. Then you produce your program, save it, and download it to your computer. The term 'download' is a bit misleading in this context, because what you are actually doing is compiling the program as a hex file that is then downloaded to your computer. It is then transferred to the micro:bit, which appears as an ordinary USB drive when connected to a computer. The new file replaces the existing program, and starts to run as soon as the loading process has been completed.

There are two main programming languages for the micro:bit, which are the block editor and a version of Python called 'MicroPython'. Choosing the block editor produces a menu system on the left of the screen that provides access to various programming commands, variables, and so on. Fig.3 shows the various reading and writing options available via the Pins menu. A program is produced by dragging blocks onto the main screen area, adding any necessary parameters, and then assembling the blocks in jigsaw fashion.

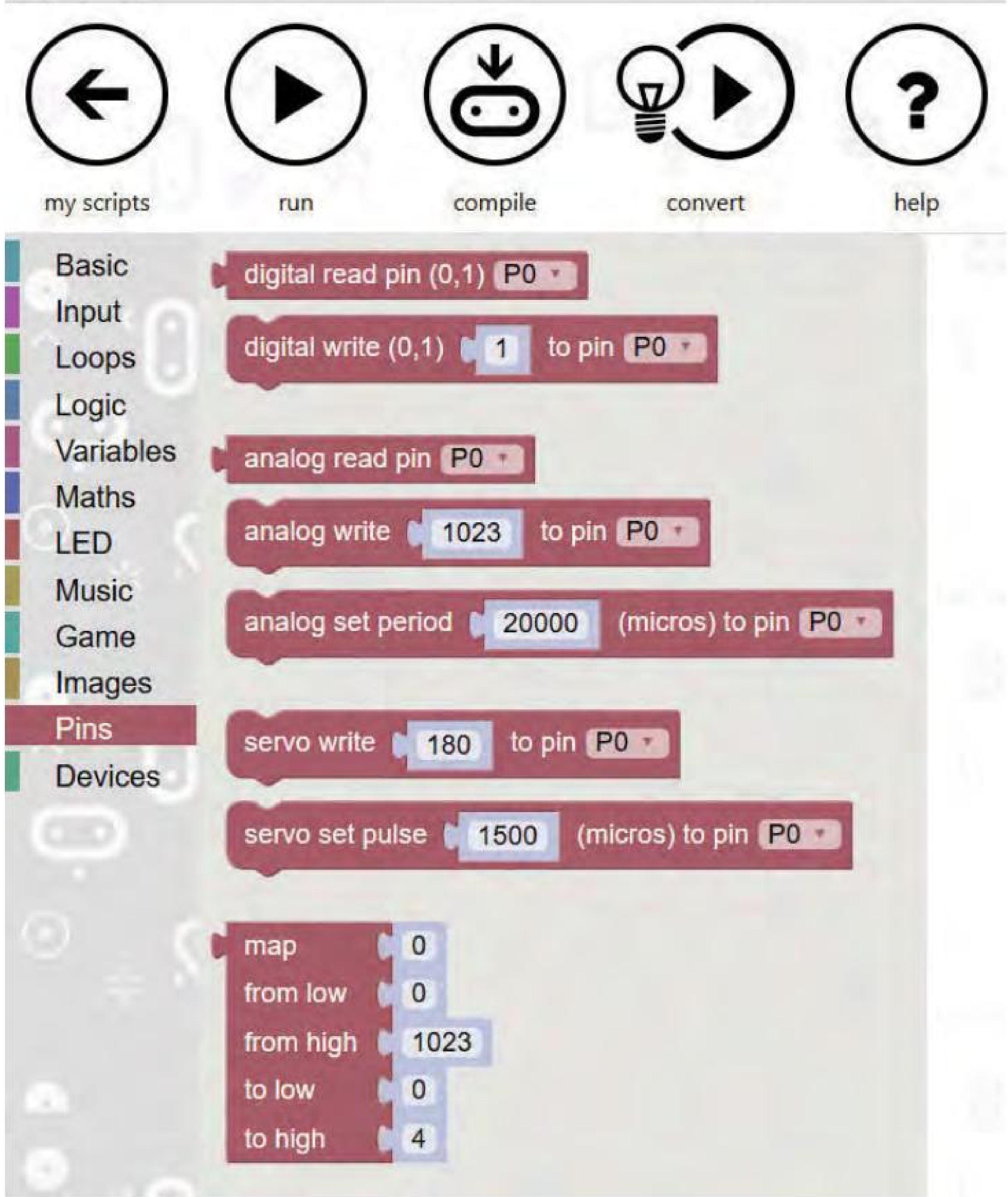

my scripts
run
compile
convert
help
Basic
Input
Loops
Logic
Variables
Maths
LED
Music
Game
Images
Pins
Devices
digital read pin (0,1) P0
digital write (0,1) 1 to pin P0
analog read pin P0
analog write 1023 to pin P0
analog set period 20000 (micros) to pin P0
servo write 180 to pin P0
servo set pulse 1500 (micros) to pin P0
map 0
from low 0
from high 1023
to low 0
to high 4

Fig.3. A menu system provides access to various programming blocks. These are the blocks associated with the input/output pins

Fig.4 shows a simple example that repeatedly reads an analogue value from pin 0 and displays it on the scrolling LED display. Infinite loops are something that must be avoided with most programming, but micro:bit programs will normally be required to run continuously from switch-on to switch-off. Consequently, most micro:bit programs will run in an infinite loop, which in this case is provided by a 'forever' loop.

In order to read a value from a pin, a variable must first be declared. In this example the variable is called 'ReadValue'. This becomes a block that can be added to an 'analog read pin' block. The value in this variable is then displayed using a 'show number' block. A short delay is then used to ensure that the display provides a small gap between one reading and the next. A simple menu system at the top of the page provides options to test programs via a simple on-screen emulator, and to compile/download them ready for transfer to the micro:bit.

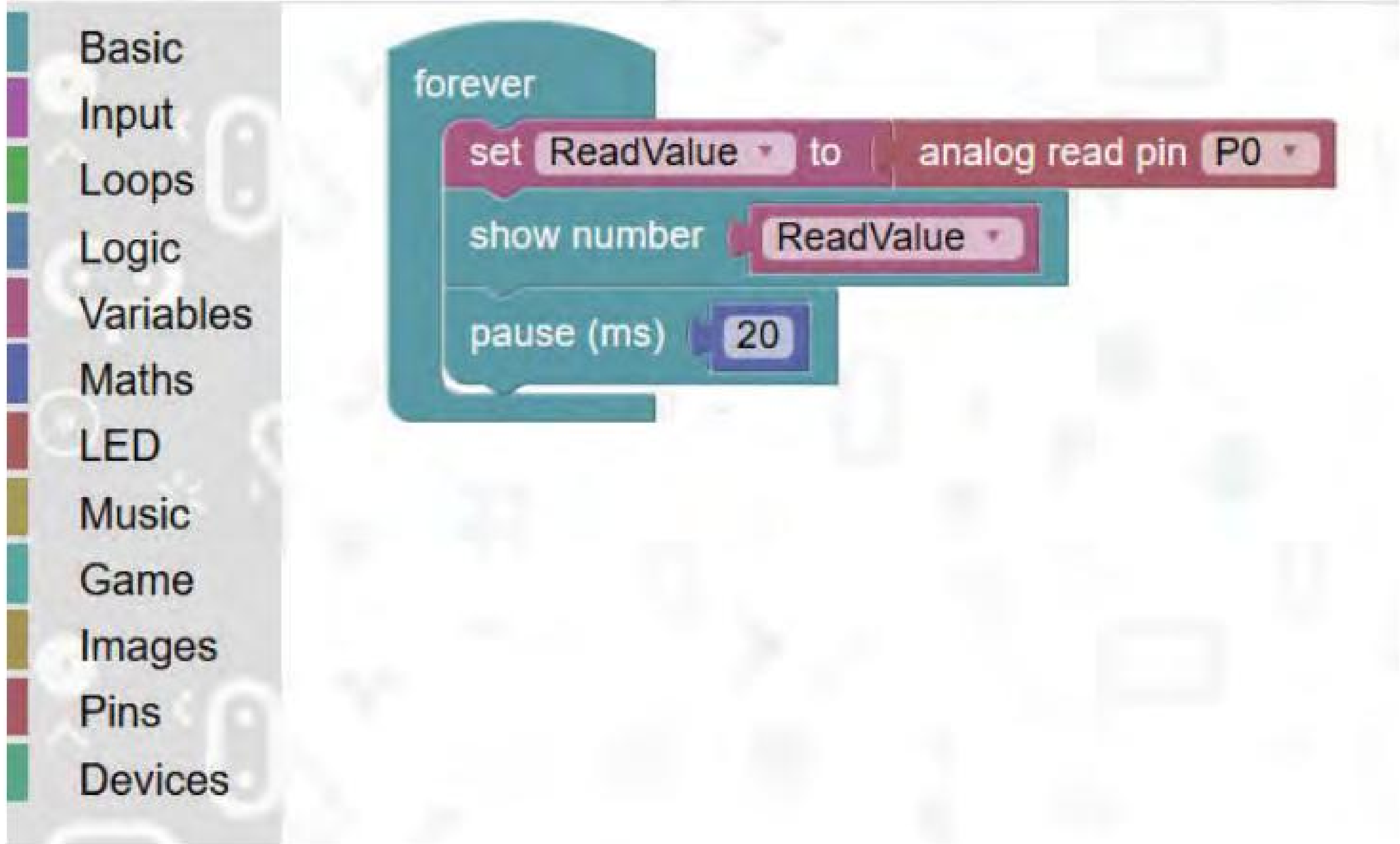

Basic
Input
Loops
Logic
Variables
Maths
LED
Music
Game
Images
Pins
Devices
forever
set ReadValue to analog read pin P0
show number ReadValue
pause (ms) 20

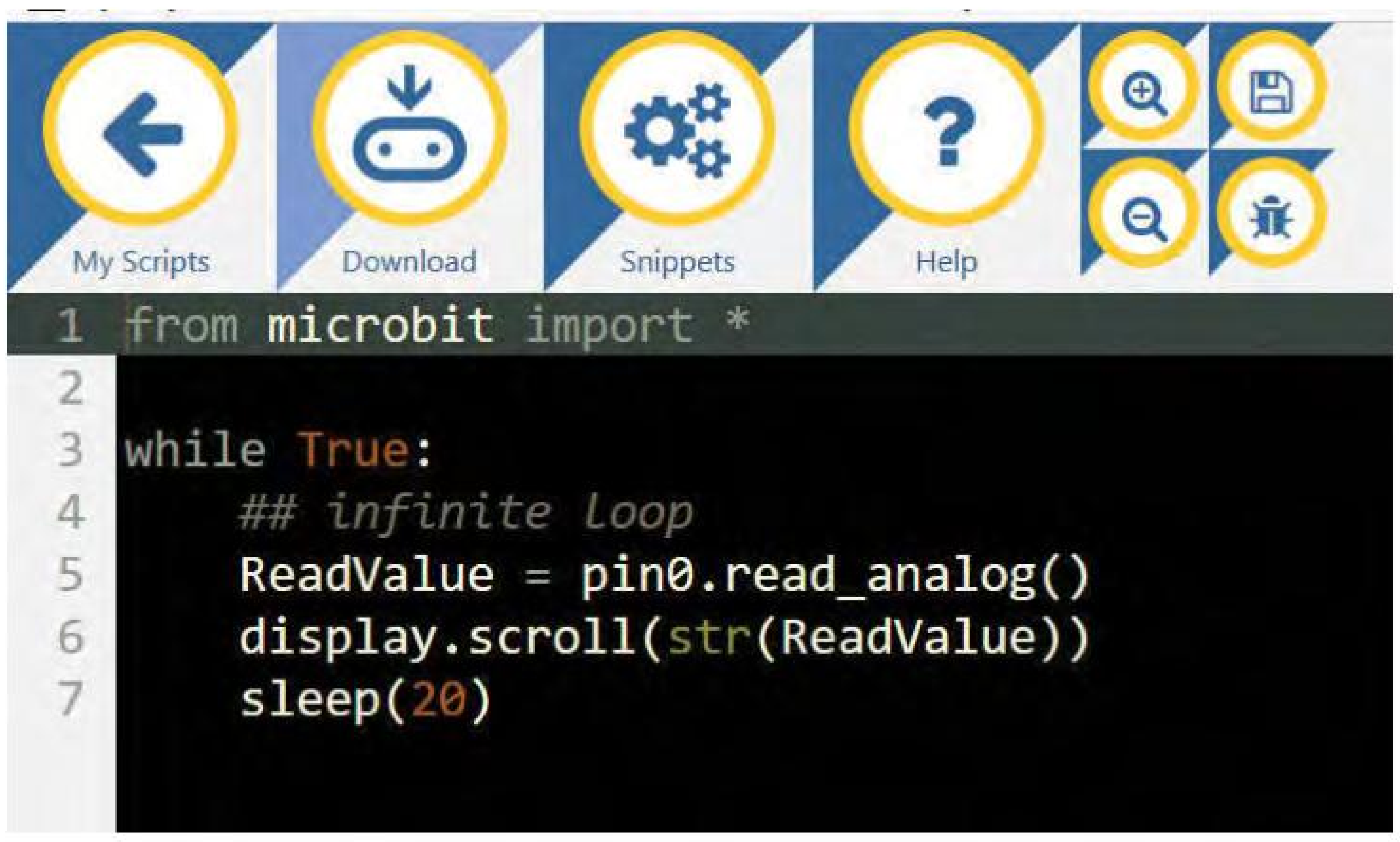
Fig.4. A simple block program that repeatedly reads and displays analogue readings from pin 0. A 'forever' block provides an infinite loop

Using the block editor makes things relatively easy for those new to programming, and it avoids minor but irksome and time-consuming syntax errors. In order to fully exploit the micro:bit though, it is necessary to resort to a conventional programming language such as MicroPython. Experienced programmers would be well advised to use MicroPython from the start. Choosing this programming option brings up a page that has a conventional editor where the program is entered. It is not essential to use this, and it is possible to write programs in another editor and then use the Copy and Paste method to transfer them to the online editor.

The first line of the example program in Fig.5 simply loads the micro:bit module that provides the special Python instructions, such as those associated with the input/output pins. There seems to be no MicroPython equivalent of the 'forever' loop of the block editor, and a while… loop at line 3 is therefore used to provide an infinite loop. Lines 5 to 7 read the converter, output it to the scrolling display, and provide a short delay, as in the block version of the program. The large Download button at the top of the page is then used to compile the program to a hex file, and download it to the computer.

Problems, problems

While it is possible to obtain excellent results from an analogue input of the micro:bit, in practice it is necessary to be aware of a few shortcomings that could seriously affect the accuracy of readings. The first thing that I noticed when experimenting with an analogue input was that the full range of values from 0 to 1023 was not quite obtained. Connecting the analogue input to the 0V and 3V supply rails produced readings of 3 and 1022 respectively. The very slight shortfall in the higher reading is not of great practical importance, but the offset from zero is of greater concern.


My Scripts
Download
Snippets
Help

```
1 from microbit import *
2
3 while True:
4     ## infinite loop
5     ReadValue = pin0.read_analog()
6     display.scroll(str(ReadValue))
7     sleep(20)
```

Fig.5. The MicroPython equivalent of the block program in Fig.4 – in this case a while… loop is used to provide indefinite looping

It was possible to obtain a full range of values using an external voltage source, albeit with a small negative voltage being needed to obtain a reading of zero.

This might have just been a peculiarity of the particular micro:bit I was using, or the problem could be more widespread. The easy solution is to use software to compensate for any positive offset at the low end of the range, and to accept that the maximum reading will be around 1019 rather than 1023. With the offset removed in software, good results with excellent linearity were obtained. Unlike the notoriously noisy analogue inputs of the BBC Model B computer, readings from the micro:bit inputs were found to be very stable.

Another point to bear in mind is that although the input resistance at an analogue pin is quite high, it seems to be in the region of a few hundred kilohms, it is not the hundreds of megohms provided by some analogue-to-digital converters. This will be of no importance with most semiconductor sensors or with anything else that provides a low output impedance, but it might be necessary to use a buffer amplifier with sources that have a medium or high output impedance.

The most important shortcoming of a micro:bit analogue input is that it uses the supply rails to provide the reference voltage that sets the full-scale input potential. As with any converter of this type, it is dependent on a stable supply voltage. Any variations in the supply voltage produce corresponding changes in the full-scale input potential of the converter. As already pointed out, the supply does not seem to be fully stable when using a USB port as the power source, and it can vary substantially when using a battery supply.

Any variation in the supply voltage is not important when driving an input from the supply lines via a true potential divider, where both elements of the divider provide pure resistance; for example, when using a resistor and a thermistor or light-dependent resistor. Any change in the supply voltage will give a proportionate change in the output voltage of the divider, and readings should remain unchanged. With any other signal sources, a change in the supply potential will cause a proportionate change in readings.

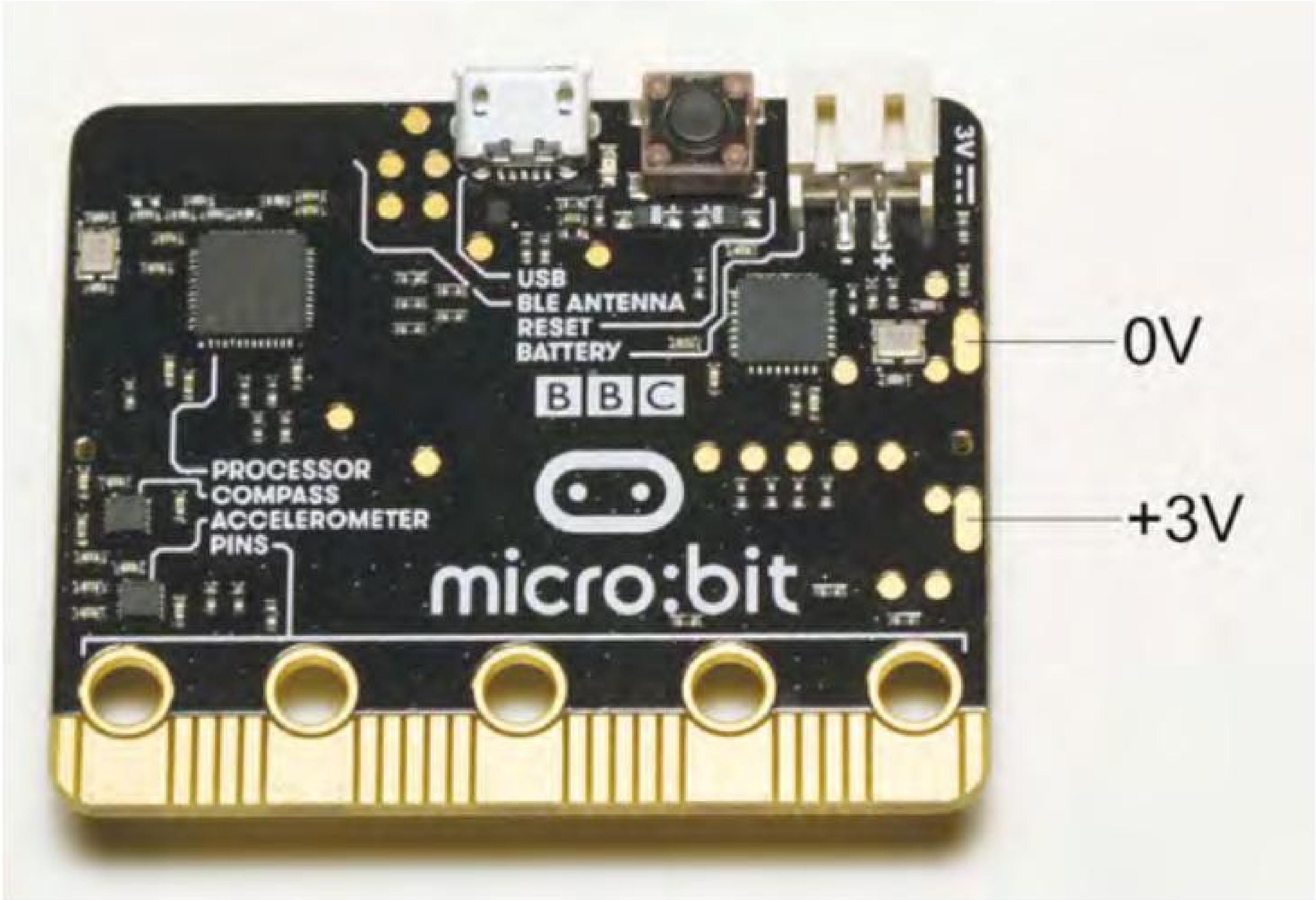


Fig.6. The reverse side of the micro:bit, showing the two power connector pads. Using these pads looks as though it might be a little risky, and due care would have to be exercised.

Supply options

When driving an analogue input with something other than a simple potential divider it is preferable to use a USB port as the power source rather than a 3V battery pack. In fact, the voltage variations from a battery are such that the accuracy would vary so greatly as to render the system of little practical value. Although variations in loading cause some fluctuations in the supply voltage when using a USB power source, they are relatively small. It would probably be possible to obtain more stable results by ensuring that the LED display is always in the same state when readings are taken. For example, it could be cleared before taking a reading, so that it provides no loading of the supply.

Of course, it is possible to use a power source other than the battery pack or a USB port. Due care must be taken when using an alternative power source, since using the wrong polarity or even a slightly excessive supply potential could damage the micro:bit. It is probably best to ensure that the supply is never more than about 3.5V. Power can be applied via the battery connector at the top left-hand corner of the board, or using the 3V and GND pins of the GPIO port. There are also two oval shaped pads on the board that can be used (Fig.6). If it is essential to use battery power, using three 1.5V cells via a 3.3V low-drop-out regulator should provide a stable supply, and improved uniformity from the analogue inputs.

Power for peripheral circuits can be drawn from the GPIO port, but only a fairly limited maximum output current is available when using a USB port as the power source. There is an on-board regulator that is used to drop the 5V USB supply to the 3.3V required by the micro:bit's hardware. This can supply up to 120mA, but the current consumption of the micro:bit has to be taken into account when calculating the available current. The current drain of the board itself seems to vary considerably depending on the hardware in use, but seems to be mainly governed by the number of active LEDs in the display.

The maximum current consumption in practice seems to be about 70mA, which means that there will usually be no problems if no more than 50mA is drawn from the GPIO port. The regulator is not used for power sources other than the USB port. Of course, when using the battery pack it is important to avoid having high currents through the board that could 'blow' the copper tracks.

The micro:bit certainly has some potential for use in sophisticated projects. The simple scrolling LED display is quite effective, but is perhaps a bit slow and limiting for some applications. It is adequate for simple test and measuring devices. For anything more than this it would probably be best to resort to one of the serial interfaces on the GPIO port, where proper displays and other sophisticated hardware could be added.

CRICKLEWOOD ELECTRONICS
Established 1981

Frustrated with your supplier?
Visit our component packed website for a vast range of parts - old and new, many unavailable elsewhere!
www.cricklewoodelectronics.com

1000's OF PRICES REDUCED!

Alternatively phone us on 020 8452 0161 with your requirements.

Visit our Shop, Call or Buy online at:
www.cricklewoodelectronics.com
020 8452 0161
Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET

Electronics & Robotics for Makers

TinyDuino

As powerful as the Arduino Uno but smaller than a 2 pence coin.

Complete with a wide and growing range of TinyShields - where will your next project take you?

All the power of the Arduino in a fraction of the space, great for building intelligence in to your projects.

STEMTera Breadboard

A breadboard with built-in Arduino! The breadboard has a total of 41 I/O pins of which 9 provide PWM. Pin-to-pin compatible with **Arduino UNO R3** shield. The bottom cover is Lego® compatible and will fit base plates and bricks - great for Robotics and Animatronics.

Fully **Arduino IDE** compatible and built with strong ABS plastic and is available in a range of colours.

Edison Robot

Edison is great for schools and hobbyists alike to teach kids robotics and programming on any computer, tablet or phone.

Edison is a LEGO compatible robot which means your kids can let their imagination run wild. Why not make a remote control LEGO

There's a lot that one Edison Robot can do, imagine what your kids can do with a team of them working together!

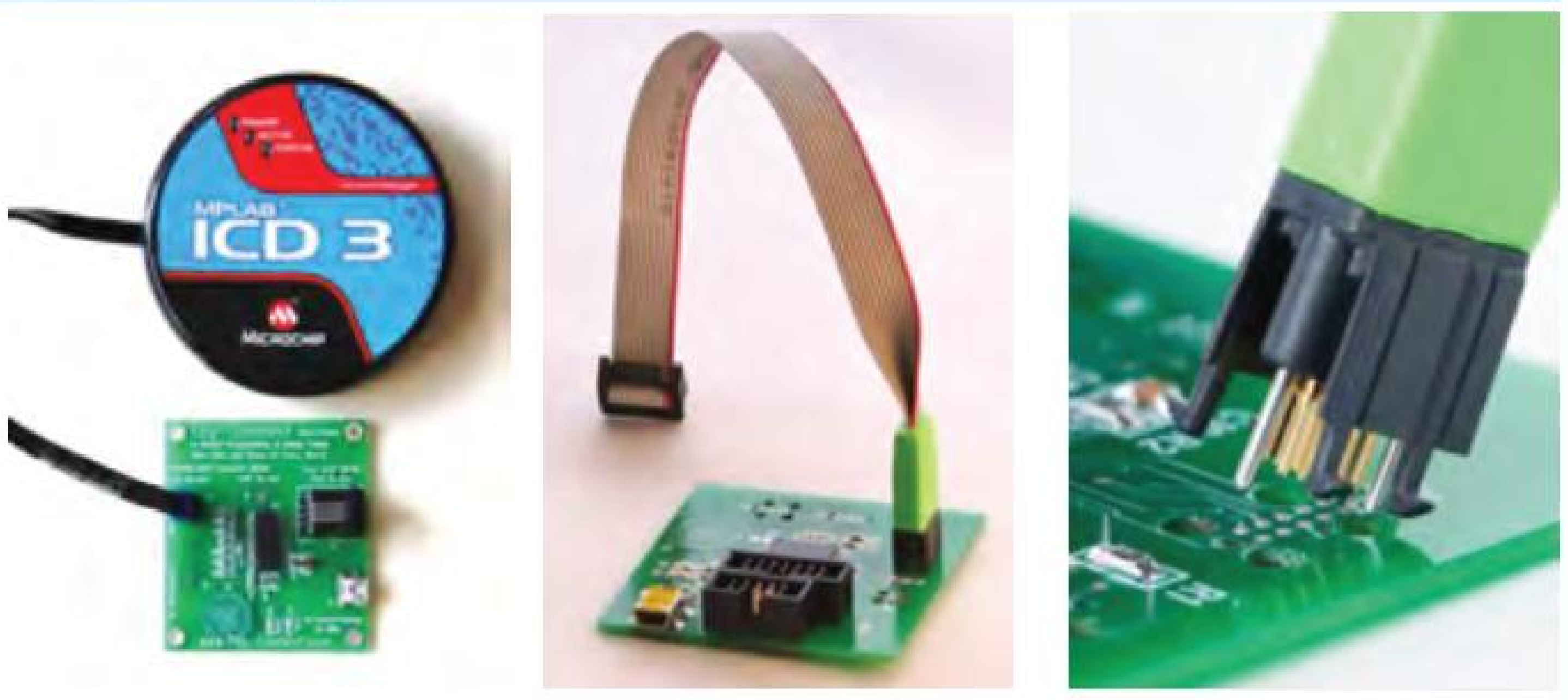
Supporting Education

Supporting *Makers*

iCSAT

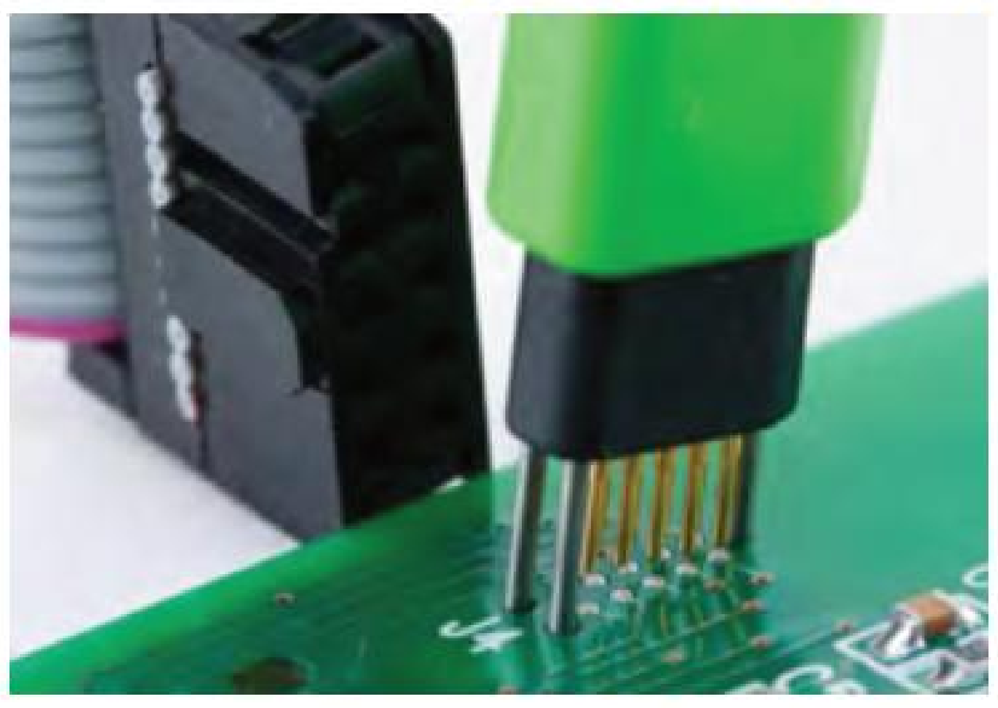
www.eshop.icsat.co.uk

Tag-Connect



JTAG Connector Plugs Directly into PCB!!

No Header! *No Brainer!*



Our patented range of Plug-of-Nails™ spring-pin cables plug directly into a tiny footprint of pads and locating holes in your PCB, eliminating the need for a mating header. Save Cost & Space on Every PCB!!

Solutions for: PIC . dsPIC . ARM . MSP430 . Atmel . Generic JTAG . Altera Xilinx . BDM . C2000 . SPY-BI-WIRE . SPI / IIC . Altium Mini-HDMI . & More

www.PlugOfNails.com

Tag-Connector footprints as small as 0.02 sq. inch (0.13 sq cm)

pico®
Technology

THE PICOSCOPE 4444

NEW SEE THE DIFFERENCE

A NEW STANDARD IN DIFFERENTIAL MEASUREMENT

- 20 MHz bandwidth, 12 - 14 bit resolution
- 4 fully differential inputs
- 1000 V CAT III probes
- Low voltage probes and current clamps

For more information please visit
www.picotech.com/PS514

Prices are correct at the time of publication. Sales taxes not included.
Please contact Pico Technology for the latest prices before ordering.
Email: sales@picotech.com. Errors and omissions excepted.

PIC n' Mix

Mike O'Keeffe

Our periodic column for PIC programming enlightenment

PICs and the PICkit 3: A beginner's guide – Part 10

I WAS pleased with the way last month's *LED Binary Clock* combined many of the different techniques we have covered over the last few months, and I hope you enjoyed having a crack at building one. We are now moving towards the end of the beginner's guide series, and the lessons will become a little more difficult. However, I will endeavour to keep the high-level concepts easy to understand as we dip our toes into some of the trickier features of each topic. This month, we're going to look at Lesson 10: Interrupts and Pull-Ups from the *PICkit 3 Starter Kit User's Guide*.

First, as always, I recommend having a read of the previous articles in the series. It's not necessary for this article, but you will gain a greater insight into PICs and what we're trying to achieve here. You will also need the following software and hardware:

1. Purchase the PICkit 3 Low Pin Count Demo Board (**http://tinyurl.com/h2jj2ek**)
2. Purchase the PICkit 3 Programmer + USB Cable (**http://tinyurl.com/zcpx3le**)
3. Download *PICkit 3 Starter Kit User's Guide* (**http://tinyurl.com/jyqfeuk**)
4. Download MPLAB X IDE (**http://tinyurl.com/hmehqja**)
5. Download XC8 Compiler (**http://tinyurl.com/h5g9k5l**)
6. Download Example code for PICKit3 Starter Kit (**http://tinyurl.com/z2dm5k3**)

I've mentioned interrupts a number of times in previous articles. Now it's time to take a proper look at what they are and what they can do. An interrupt is a signal emitted by hardware or software telling the microprocessor that an event needs *immediate* attention.

An example of an interrupt in operation is an external button connected to a pin. When the button is pressed, an interrupt can be used to inform the microprocessor that this event has occurred and that it has to handle it straight away. The microprocessor pauses its normal activity to service this interrupt using an ISR (Interrupt Service Routine). The ISR then filters the interrupt into high and low priorities, figures out where the interrupt came from and then executes a piece of code to 'handle' that interrupt. Once the interrupt has been 'handled', the microprocessor will resume its normal behaviour.

Another example of an interrupt would be an internal timer, like Timer0. When it reaches its maximum count (or counts down to 0), it sets its interrupt flag, which triggers an interrupt that needs to be handled immediately. This timer interrupt can be used to periodically check any number of things, like read the value from a temperature sensor or capture the state of an external pin.

Interrupts versus polling

To detect a change in state of an incoming signal (whether it's internal or external), there are two options. The first is via interrupts, as described above, and the second is called 'polling'. The concept of polling is to actively find out what state a signal is in. So, while interrupts operate in the background, polling works in the main area of code. Polling is akin to periodically 'asking' what state a signal is in. The difference here is that with polling, we only find out the state of the signal when we ask it, and the result is that polling may take longer to detect a change of state. In theory, we could miss a change altogether if the change only lasts between a polling state check.

```
if(LATCbits.LATC3 == 1) {
    … do something here
}
```

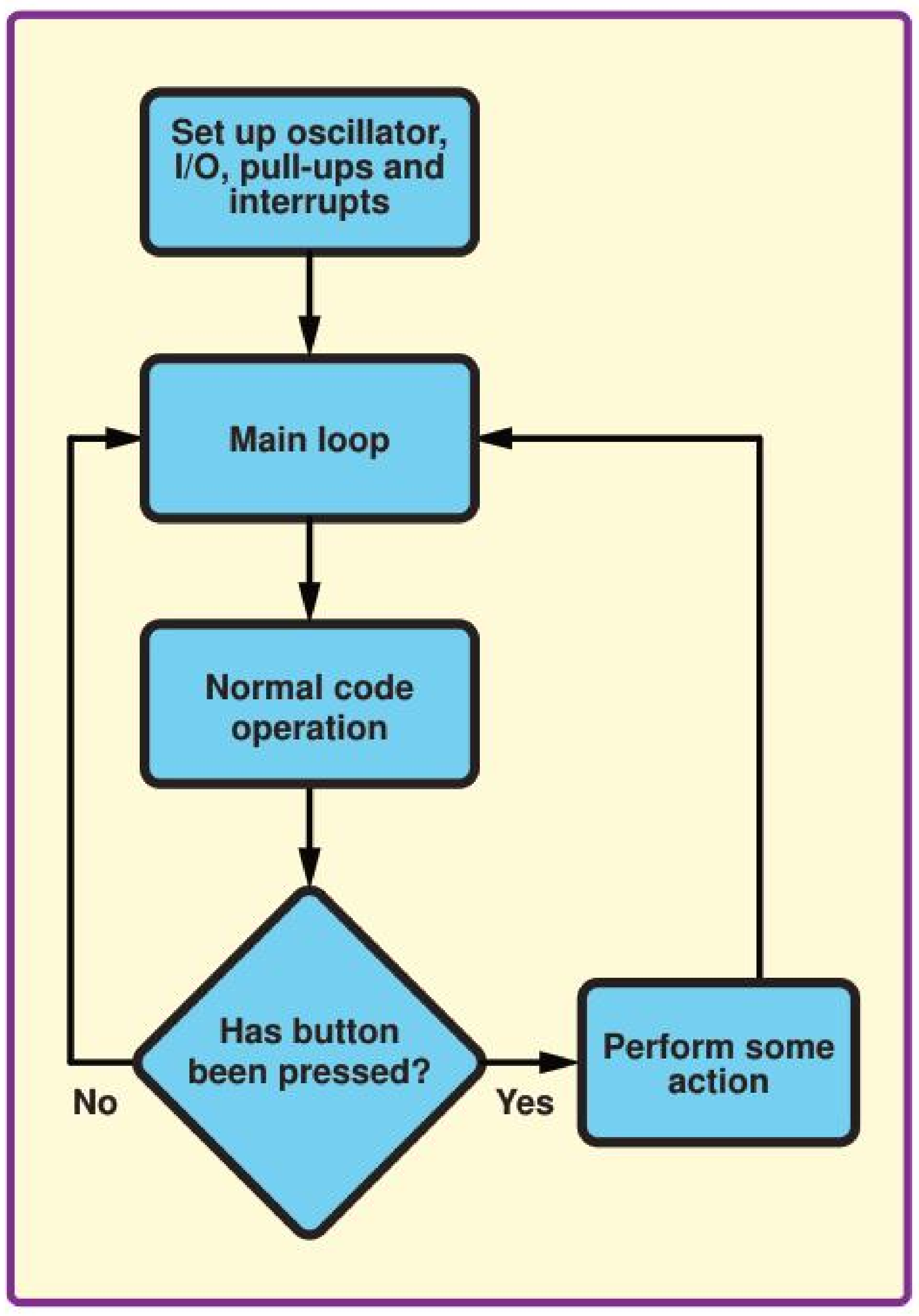


Fig.1. Flowchart showing polling function

The above is an example of polling the external pin C3. LATCbits.LATC3 returns the state of the port C3 and the `if` statement checks if it is equal to '1'. If this is true, then some code is executed. Fig.1 shows how to 'poll' an external pin to see if a button has been pressed. This code operates inside the normal code operation. If the code takes a long time performing other tasks, it might not even detect a button press.

On the other hand, with interrupts, a change in signal state is captured very quickly, without interference to the code flow. It's best to think of interrupts as another module inside the microprocessor that can run in the background, separate to the main code. This means you can run any code you want without having to periodically check some signal to see if it's changed. The interrupt module will handle the checking, let you know when an event has occurred, perform some action based on that, before returning back to your main code. Fig.2 shows a flow chart of the operation of an interrupt that checks if an external button has been pressed. The main loop now doesn't have to check if the button is pressed, as it's handled by the ISR. The advantage here is that the button press will be detected and handled as soon as the button press happens, instead of waiting around as in Fig.1. Typically, interrupts are used for urgent and infrequent events.

If interrupts are so great, why would anyone ever use polling? Interrupts were developed to solve problems with the relative slowness of polling. However, the microprocessor has a limit on how many interrupts it can handle. Therefore, interrupts should be reserved for 'emergencies' – events that need to be serviced as quickly as possible. Also, the number of interrupts should be kept as low as possible to minimise interruption to the main code flow. Polling is still useful for non-urgent enquiries where you want to confirm the state of something before proceeding. For example, checking the output of a pin connected to an LED. (eg to check if an LED is on and that nothing has gone awry in the code). An interrupt could only see the rising or falling edge, but can't tell the current state.

To summarise, interrupts are for calling the fire brigade – polling is

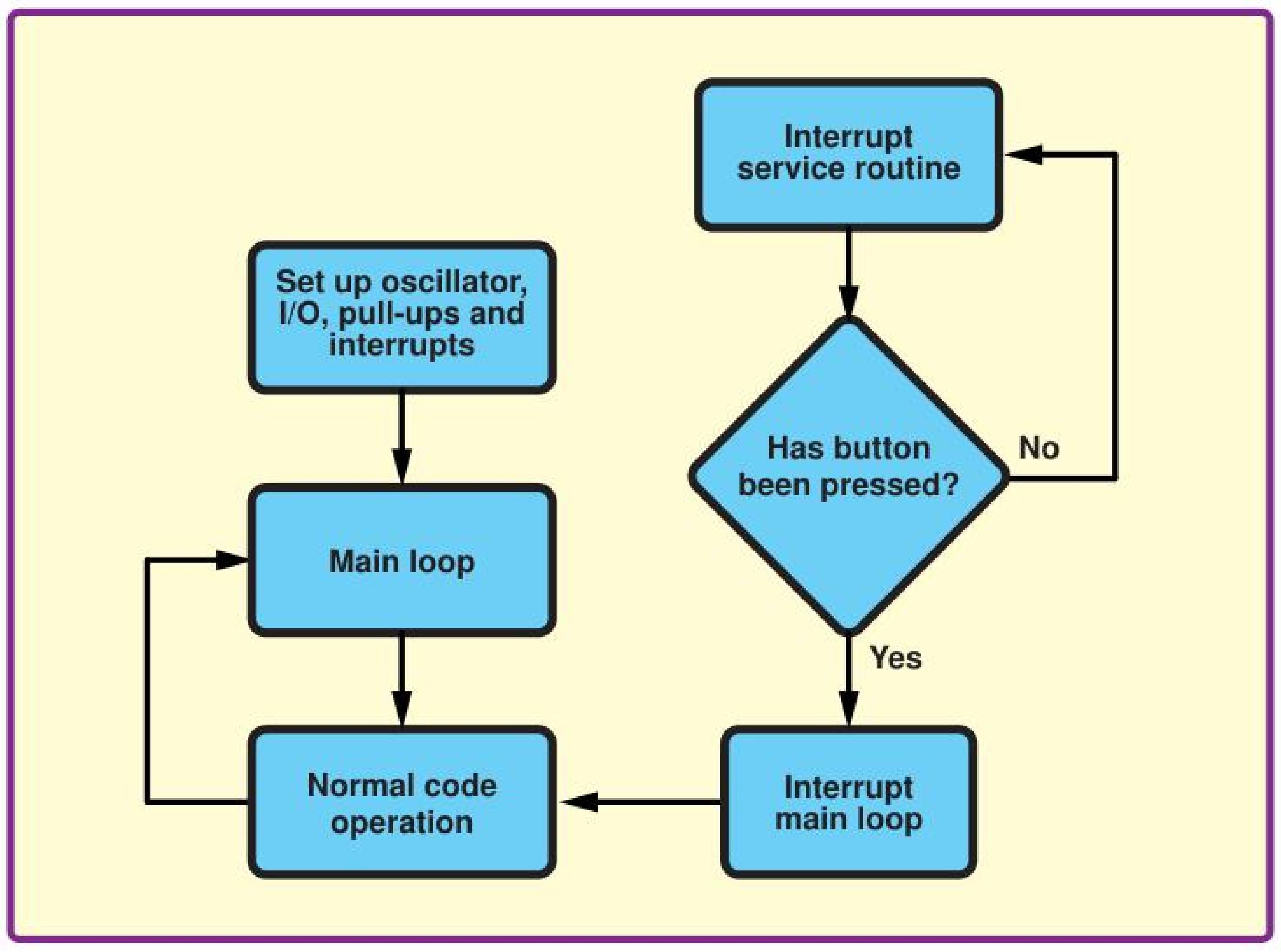


Fig.2. Flowchart showing function of interrupts

checking to see if you've got enough milk in the fridge to make tea! Both are necessary, but they represent very different levels of urgency and speed-of-response requirements.

Software and hardware interrupts

The microprocessor can handle two different types of interrupts, internally driven (software) or externally driven (hardware). We will see an example of each later in the software.

Nested interrupts

One of the most dangerous things about interrupts is 'nesting'. This is when an interrupt event occurs while the microprocessor is servicing an interrupt event from the same signal. It is possible to have multiple interrupt events and 'nesting' even further. This can cause the microprocessor to lock up, while trying to handle all of the events simultaneously.

In order to overcome this problem it is necessary to disable the current interrupt as soon as an ISR is called. Then before returning to the main code, it is necessary to re-enable interrupts. (As an aside from PICs, this is something some ARM processors can handle using their NVIC (Nested Vector Interrupt Controller), which queue up each interrupt to be sorted and handled individually based on what came first and priorities.)

Pull-ups and pull-downs

Before looking at the sample code for interrupts, let's have a quick look at pull ups. In the world of signals, we're always aware of what state each signal is in at any given time. In a digital system, we have three basic states, high (VDD), low (GND) and floating (anywhere between VDD and GND). Ideally we want to keep away from floating signals as they can have unpredictable effects on a system. If a signal pin is 'floating' when it is read, it can sometimes read as high and sometimes read as low, it's completely random. This is where pull-ups are used to control a signal pins state.

What exactly is a pull-up though? In effect it is a resistor connecting our signal or pin of interest to VDD. In last month's *LED Binary Clock*, we used a 10kΩ pull-up resistor to VDD in order to keep the cathode side of the LED's high when the transistor was not turned on.

I think it's only fair to mention 'pull-downs' here. They're not used as often as pull-ups, but their function is exactly the same. However instead of pulling the signal up to VDD, they pull a signal down to ground/0V instead. These can be used on the base of an NPN transistor to ensure it is in the 'off' state, while the base is not controlled by the PIC.

Internal and external pull-ups

For the purposes of this lesson, the focus is on internal pull-ups that are controlled by the PIC firmware. These internal pull-ups can be enabled and disabled in software without needing any external components. However, these will only be weak pull-ups. If we want a stronger pull-up, we would need to add an external resistor connected to VDD. The internal pull-ups are usually sufficient for most cases and are a great cost and space-saving feature of PICs, as no external resistors are needed.

Weak versus strong pull-ups

When we talk about pull-ups, we are always interested in the 'strength' of that pull-up. What we really mean is how quickly the pin on our microprocessor will move up to VDD or down to GND. The pull-up acts as a current limit, which in turn limits the rate of change of the voltage. Keeping in mind Ohm's law ($V = IR$), if the resistance decreases (strong), the current will increase, allowing a faster change in voltage. The inverse is true, whereby if the resistance increases (weak), the current will decrease and the voltage change will be slower.

A PIC will use a very weak pull-up inside the microprocessor itself. This is more of a safety measure to limit the amount of current being drawn by the pin.

Strong pull-ups are typically used to reduce noise currents from unintended coupling and EMI (electromagnetic interference). Unfortunately, they draw more current, which is a factor in low-power designs. Ideally, we always want to minimise power use and noise levels, so there's a compromise to be struck. The rule of thumb here is to use weak pull-ups, ranging from 4.7kΩ to 47kΩ for most cases (including our button example). Strong pull-ups can be used when you want to make sure a signal is always high (for example, the reset pin on your microprocessor, if you want to make it impossible to reset the device, add a strong pull-up).

Software

Now we have a rough idea of the basic interrupt concept, lets take a look at some demonstration code. The code provided for this lesson is derived from Lesson 9: Timer0. By using interrupts, the following code is more efficient than the same example code in Lesson 9, as it is no longer waiting for Timer0 to roll over.

```
#define LED_RIGHT    1
#define LED_LEFT     0
#define PULL_UPS

unsigned char _direction;
void main(void) {

    OSCCON = 0b00111000;
    TRISC = 0;
    LATC = 0;
    LATCbits.LATC3 = 1;
    _direction = LED_RIGHT;
    TRISAbits.TRISA2 = 1;
    ANSELAbits.ANSA2 = 0;
```

Most of this code has been covered in previous articles. It starts off defining two variables `LED_RIGHT` and `LED_LEFT`. While this is not necessary for the code to work, it does make reading the code a lot easier as you deal with a descriptive name instead of a '1' or a '0' – and never forget, this is not a trivial reason. (Being able to decipher code some time after you have written it is very important if you value your sanity!) We have another definition here as well, `PULL_UPS`, which is covered below. Next, the code initialises a global variable `char _direction` (as it's outside the main loop), followed by setup of the internal oscillator using `OSCCON`, and then port setup using `TRISC` and `LATC`. Next up, C3 is set high, the direction of the LEDs is set to move right (see how the variable name is much better than a non-descriptive '1'). Last, A2 is set as an analog input.

```
#ifdef PULL_UPS
    WPUA2 = 1;
    nWPUEN = 0;
#endif
```

We have three new things going on here. First, we have the pre-processor definitions `#ifdef` and `#endif`. The code between these two definitions will only be executed if the variable `PULL_UPS` is defined. As we've seen above, it is defined. If we comment out the `#define` for `PULL_UPS` then the code here would not be executed, which is a useful way of enabling and disabling various pieces of code without having to manually comment out each line.

Next, WPUA2, which is short for 'weak pull-up on A2'. This enables the weak pull-up on A2, which is externally connected to the button. This pull-up ensures the signal is high until the button is pressed and then it is pulled low.

nWPUEN then enables all weak pull-ups using each WPUx latch values. As we've only called WPUA2, then only A2 will have it's pull-up enabled.

```
    OPTION_REG = 0b00000111;
    INTCONbits.TMR0IE = 1;
    INTCONbits.IOCIE = 1;
    IOCANbits.IOCAN2 = 1;
    GIE = 1;

    while (1) {
        continue;
    }
}
```

To finish off the rest of the main code, we have OPTION_REG and TIMER0 interrupt enable, which we've seen in Lesson 9: Timer0. The new parts here are INTCONBITS.IOCIE, IOCANBITS.IOCAN2 and GIE. INTCONBITS.IOCIE is the interrupt on the change enable bit. When this is set, it will generate an interrupt on a change at the selected input.

IOCANBITS.IOCAN2 is the interrupt on change Port A negative-edge register. This register selects A2 as the input for the interrupt and sets the generation of an interrupt to only happen when a negative edge is seen.

It's probably a good idea to talk about negative and positive edges. These are also known as falling and rising edges respectively. Negative or falling edges refer to when a signal transitions from a 'high' state to a 'low' state. And the inverse is true for positive or rising edges. See Fig.3 for a clearer idea of what we're talking about. There's a good reason why we only want one or the other. When a button press occurs, the signal moves from a high to a low, then when we release the button, the signal will transition from a low to a high. This causes two interrupts to occur, making it appear the button was pressed twice. In this scenario, it doesn't really matter if we choose a negative or positive edge, we will still see a button-press action occur. However, there are other times when we prefer a negative edge over a positive edge. Typically, if we have a normally 'high' signal, we would want to capture a negative or falling edge. Again, it's the opposite for positive or rising edges.

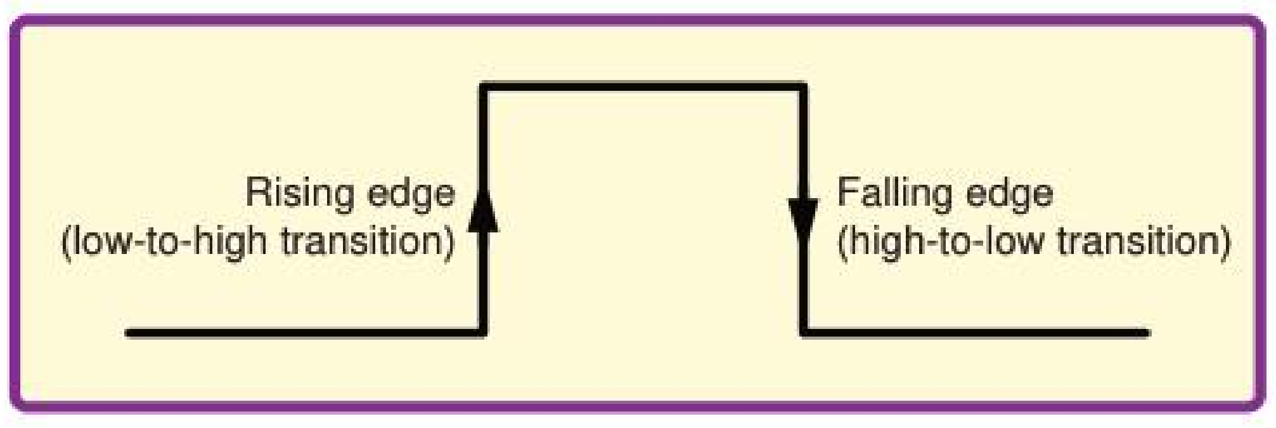


Fig.3. Rising and falling edges.

```
void interrupt ISR(void) {
    if (IOCAF) {
        IOCAF = 0;
        __delay_ms(5);
        if (SWITCH == DOWN) {
            _direction ^= 1;
        }
    }
```

Outside the main loop, there is another function. As can be seen in the main loop above, it is never called by the main loop. This because it is a separate module that has been enabled using the IOCIE and IOCAN2 registers above. The first thing to do in the ISR is check what caused the interrupt. IOCAF is the interrupt on change PORT A flag register. This flag is set when any of the enabled interrupts on Port A are triggered. If we had more than one interrupt on change in Port A, we could use IOCAF2 to be more specific about which pin we're interested in.

Next, the code clears the IOCAF flag, debounces the button and then changes the _direction variable to change the direction of the LED rotation.

```
    if (INTCONbits.T0IF) {
        INTCONbits.T0IF = 0;
        if (_direction == LED_RIGHT) {
            LATC >> = 1;
            if (STATUSbits.C == 1)
                LATCbits.LATC3 = 1;
            } else{
                LATC << = 1;
                if (LATCbits.LATC4 == 1)
                    LATCbits.LATC0 = 1;
            }
    }
}
```

The ISR should then check for other possible interrupts before exiting. We've checked the first possible interrupt source, now we need to check for other interrupts sources. The next source to check is the Timer0. We've setup the Timer0 flag to trigger an event when it has reached its maximum time. Now we check it by polling INTCONbits.T0IF to find out what state the flag is in. Quick note here, we're polling the state of the flag inside our interrupt handler, a prime example of when to use both interrupts and polling. This will occur every time the LED should be rotated. As before, we clear/reset the Timer0 interrupt flag (INTCONbits.T0IF) and we rotate the LED as we've done in multiple lessons previously. The rest of this code covering the rotation of the LEDs is covered in Lesson 9: Timer0.

Last, one important thing to note about interrupts is that the code should be short, introducing minimal delays and return to the main operating code as quickly as possible. This ensures all interrupts are dealt with efficiently.

Next month

In Part 11, next month, we're going to look at Indirect Addressing, and then Look-Up Tables and EEPROMs in the following months. Indirect addressing can be used to implement a moving average filter, which can filter out noise and smooth the input capture on an ADC. Then we'll finish with a project that uses many of the ideas introduced over the last year.

Not all of Mike's technology tinkering and discussion makes it to print.

You can follow the rest of it on Twitter at *@MikePOKeeffe*, up on *EPE Chat Zone* as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

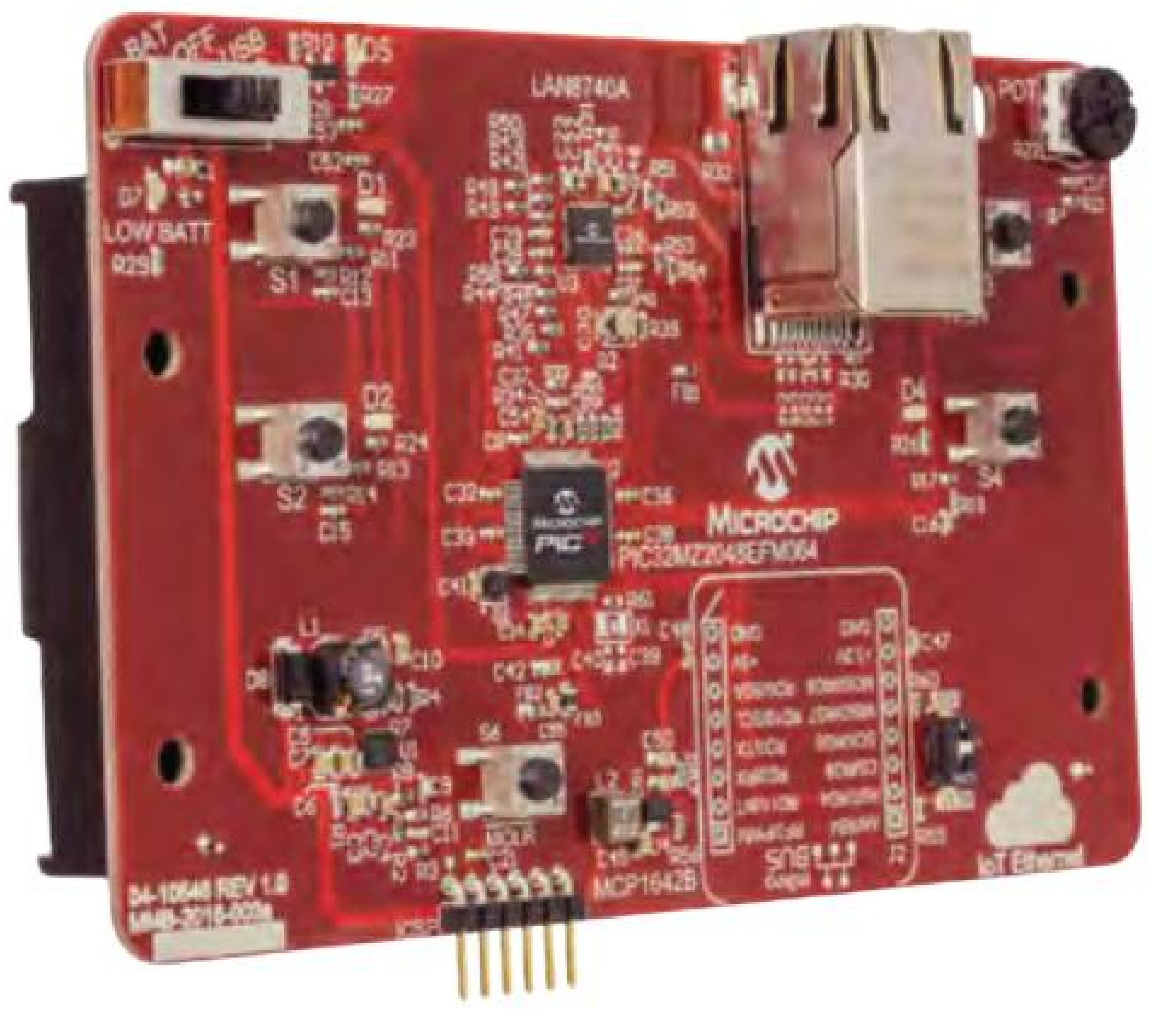
Looking to advertise?
Contact Stewart Kearn on:

01202 880299
or email

stewart.kearn@wimborne.co.uk

Development Tool of the Month!

IoT Ethernet Kit Powered by AWS IoT



Part Number
DM990004

Overview:

The IoT Ethernet Kit powered by AWS IoT uses an Ethernet LAN8740A driven by a 32-bit MCU with 2 MB of Flash (PIC32MZ EF) that provides plenty of memory space for your application. On the sensor side, hundreds of different sensors can be plugged into the MikroElektronka mikroBUS™ footprint allowing for prototyping a large variety of IoT proof-of-concepts. This kit takes advantage of the AWS IoT service and provides a smooth user experience coming preloaded with the corresponding firmware. AWS IoT is a managed cloud platform that allows connected devices to interact easily and securely with cloud applications and other devices. Additionally, the firmware in the kit makes use of MPLAB® Harmony, FreeRTOS™, WolfMQTT and WolfSSL allowing you to quick-start your IoT design.

Key Features:

- Developed as a reference for industrial Ethernet environments
- Complete development kit that includes IoT edge device and setup instructions for using AWS IoT
- Easy setup out of the box with your own AWS account
- JSON-based data payload
- Four input buttons, four output LEDs and one analog input potentiometer on edge device to show bidirectional control via AWS IoT
- mikroBUS header for extendability to build any IoT use case using available or custom sensors

Order Your IoT Ethernet Kit Powered by AWS IoT Today at: www.microchipdirect.com

The Microchip name and logo, PIC and mTouch are registered trademarks and PICtail is a trademark of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks mentioned herein are the property of their respective companies. © 2017 Microchip Technology Inc. All rights reserved. MEC2145Eng02/17

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Logic timing and timing diagrams

LAST MONTH, we looked at a pulse-width modulation (PWM) load-power control circuit from an *EPE Chat Zone* discussion started by frequent contributor ***noel***. The topic of interest then was how to vary the PMW applied voltage – presumably for testing purposes, or similar, as PWM power control usually uses a fixed voltage. As part of the general discussion of PWM we presented a basic digital circuit that could help generate PWM signals (see Fig.1). We also presented the timing diagram showing example waveforms of the circuit operating (see Fig.2). There was a small error here in that the output was shown inverted on the original schematic, but not on the waveforms (corrected in Fig.1 here). The circuit and timing diagram were a relatively minor part of the scene-setting and background on PWM, rather than part of a 'solution' to ***noel's*** question, but it prompted me to think that timing diagrams are important in digital electronics, and discussion of some of the fundamentals related to digital timing and timing diagrams would be a useful topic for *Circuit Surgery*.

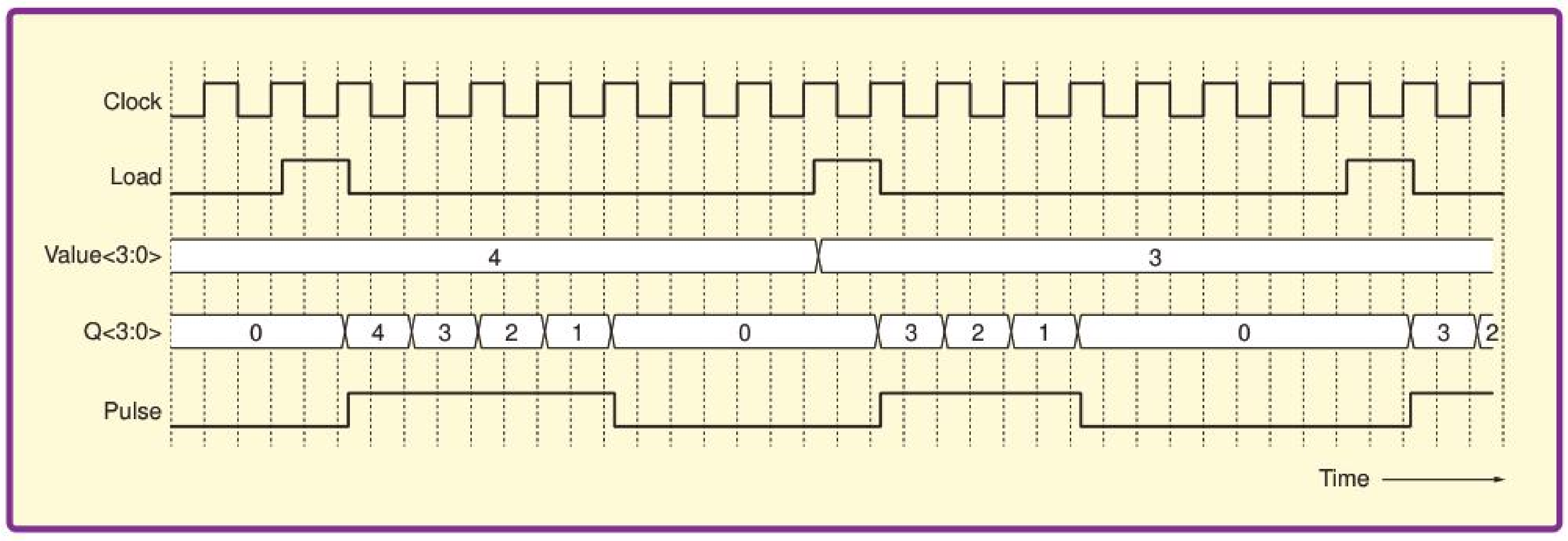


Fig.2. Waveforms for the circuit in Fig.1

Perhaps these days fewer people than in the past design and build digital circuits like those in Fig.1, particularly using boards full of 7400- or 4000-series logic. Often, the required operations can now be implemented directly with microcontrollers, using a combination of code and on-chip hardware – as discussed in the context of PWM last month. Of course, it is also very common to use a variety of specialist peripheral ICs to provide functionality or performance not available on the microcontroller. In these situations it may be necessary to study the timing diagrams in the peripheral IC's datasheet to be able to write the code to interact with the chip. In some cases, library routines for standard buses, such as SPI, can be used, but things are not always completely straightforward. Furthermore, the timing of signals between a microcontroller and other device may have to be investigated in detail during debug if there are problems. A good understanding of the basics of logic timing and the way that it is depicted on timing diagrams is valuable in such circumstances. Enthusiasts may also want to delve into the world of field-programmable gate arrays (FPGAs) and System-on-Chip (SoC) FPGAs (which have on-chip processors), where knowledge of digital timing is likely to be needed.

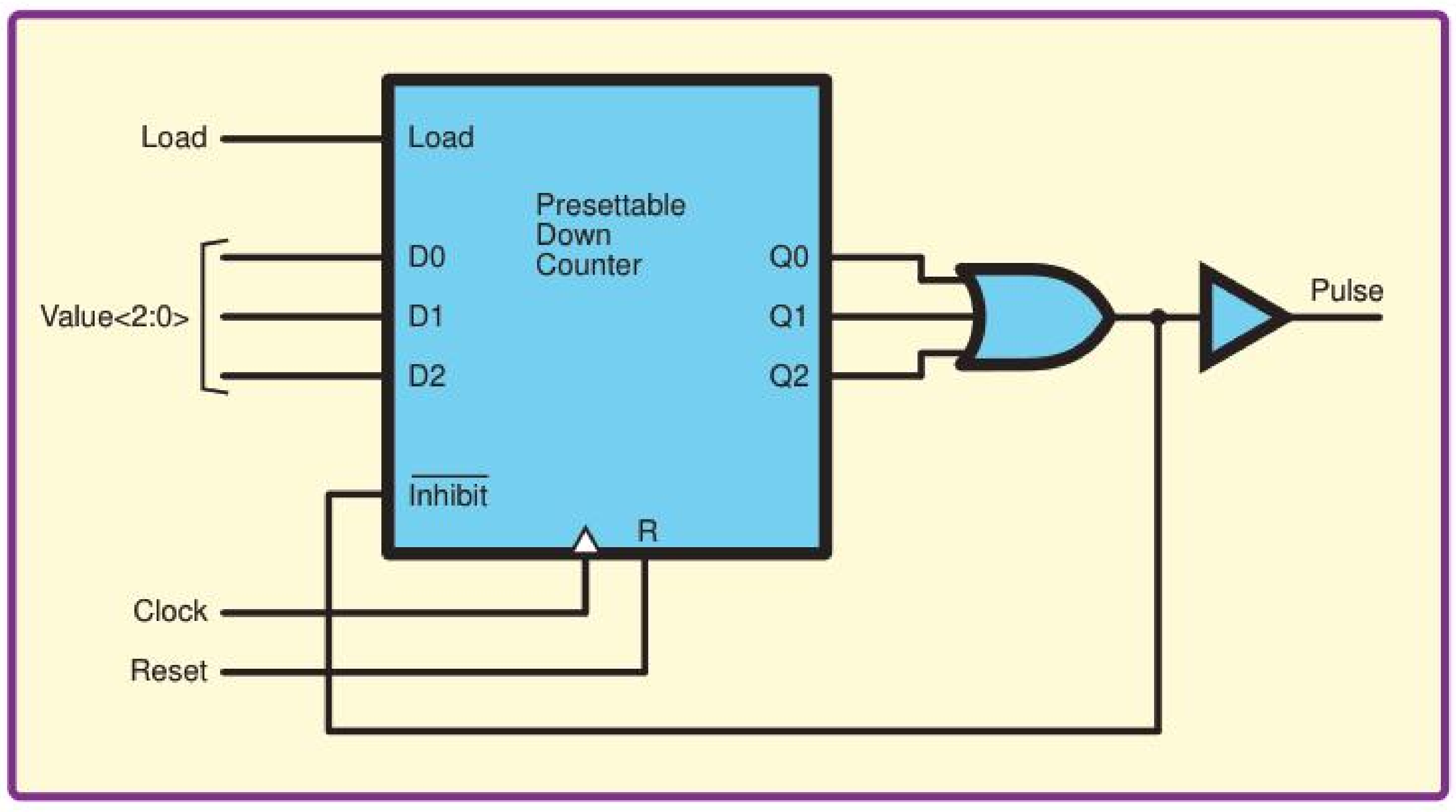


Fig.1. Presettable counter used to generate a PWM waveform

Timing diagrams

Logic timing is depicted in a number of contexts – as timing diagrams in datasheets and other technical documents; in the output of simulation of logic circuits; and in the waveforms displayed when a real circuit is investigated using a logic analyser or oscilloscope. Fundamentally, these all show the same things – the variation of the logical 1s and 0s with time as the circuit performs its function (an oscilloscope may show more analogue detail in the waveforms). Whereas simulations and 'live' monitoring will show specific details of a particular situation, timing diagrams are often generalised for the purposes of explaining circuit operation or defining timing parameters or requirements. We will show some examples of different portrayals of the same situation later.

Being able to read, interpret and draw timing diagrams requires an understanding of the basics of digital circuit timing, so we will define some terms and concepts related to digital timing, along with the discussion on timing diagrams. We will start by briefly describing some of the features of the timing diagram in Fig.2.

The time axis in Fig.2 does not show specific time values – in effect, the time axis is related to the number of pulses on the clock rather than a real time value. This is typical when the aim of the diagram is to depict the general functioning and timing of a circuit of this type, rather than the specific timing of a particular version. The circuit could be implemented in different technologies and/or operated at different clock frequencies and the same diagram would apply.

The Clock, Load and Pulse waveforms in Fig.2 are single bits (logic signals carried on a single wire) so they are shown changing between 1 and 0, with 1 represented by the trace being higher up the waveform graph. The changes between 1 and 0 are drawn vertically – in reality this change (of the voltage on the wire) is not infinitely fast, but this detail is not depicted here. Single-bit changes are sometimes shown with sloping lines – this may just be graphical style unless it is clear from the context that the actual rise (0 to 1 change) and/or fall (1 to 0 change) times are of concern.

The Value and Q waveforms in Fig.2 are multi-bit signals (carried on several wires) so values cannot be simply represented by trace position as '1' and '0'. The state of these signals at any time is written on the graph (eg, as '4' or '3' for the Value signal). The waveform is drawn using a 'box' format to show when changes occur. The 'crossovers' between the boxes are sloped here, but this does not represent the actual time taken for the change to occur.

Clocks

The majority of digital circuits have one or more clocks – a regular train of pulses which controls the overall timing of (that part of) the circuit. The clock is a bit like a drill sergeant barking 'left, right' at a group of soldiers so they all march in a synchronised fashion. Circuits whose timing is coordinated by a clock are described as being 'synchronous' – this applies to the majority of digital circuits. Often, the clock is basically a square wave (as in Fig.2) at a specific, accurately controlled frequency. The frequency may be related to the timing required for a particular protocol, for example for visual display signals or data communications. A complex system may have a number of such interfaces requiring different timing, and therefore may have multiple clocks. The circuitry associated with a given clock is said to be in a particular clock domain. Transferring data across clock domains must be done carefully to avoid potential timing problems and data errors.

Digital circuit operations that are not under the timing control of the clock are described as 'asynchronous'. Circuits can be mainly synchronous but also feature some asynchronous operations or functions, perhaps the most common example is an asynchronous reset, which puts the circuit into a well-defined state at power up, or after a crash when a user 'hits the reset'. Asynchronous resets are common in flip-flops and other devices in the 4000 and 7400 families of logic. However, resets can also be synchronous and both approaches have various advantages and disadvantages in the context of large complex circuits.

Digital systems typically process data in a step-by-step fashion, with the results of one operation being stored locally ready to use as input to the next step (see Fig.3). Such structures can be found in complex systems such as the microsteps of a microprocessor execution unit, or the mathematical operations of a digital signal processor. However, it applies in simpler cases too. We can imagine a circuit stage (or stages) before the PWM pulse generator in Fig.1, which works out what value (length) the next pulse should have and when to activate the load signal to trigger a pulse output, see Fig.4. This conforms to the general structure shown in Fig.3.

Synchronous

The circuit structure of Fig.3 is synchronous. The operation of each stage (for example deciding, counting, adding, subtracting, coding or decoding) is initiated by a specific transition of the clock (0 to 1, or 1 to 0) – known as the *active* clock edge. Thus, all operations are synchronised by the clock. The fact that an edge triggers the operation is indicated by the small triangle next to the input on the circuit symbol for the block/component, as in Fig.1 and Fig.3. If there is a small circle ('inversion bubble') between the triangle and input wire a negative-edge trigger (1 to 0) is indicated, otherwise the edge trigger is positive (0 to 1) (as in Fig.1 and Fig.3). Block symbols for positive- and negative-edge-triggered circuits are also shown in Fig.5.

The repeating part of a clock waveform is referred to as the clock cycle. If circuit activity is edge triggered then the cycle is usually considered to start at the active clock edge. Clock waveforms with clock cycles identified, for both positive and negative edge systems, are shown in Fig.5. The time duration of one clock cycle is called the clock period, T_C. The frequency of the clock is given by, $f_C = 1/T_C$.

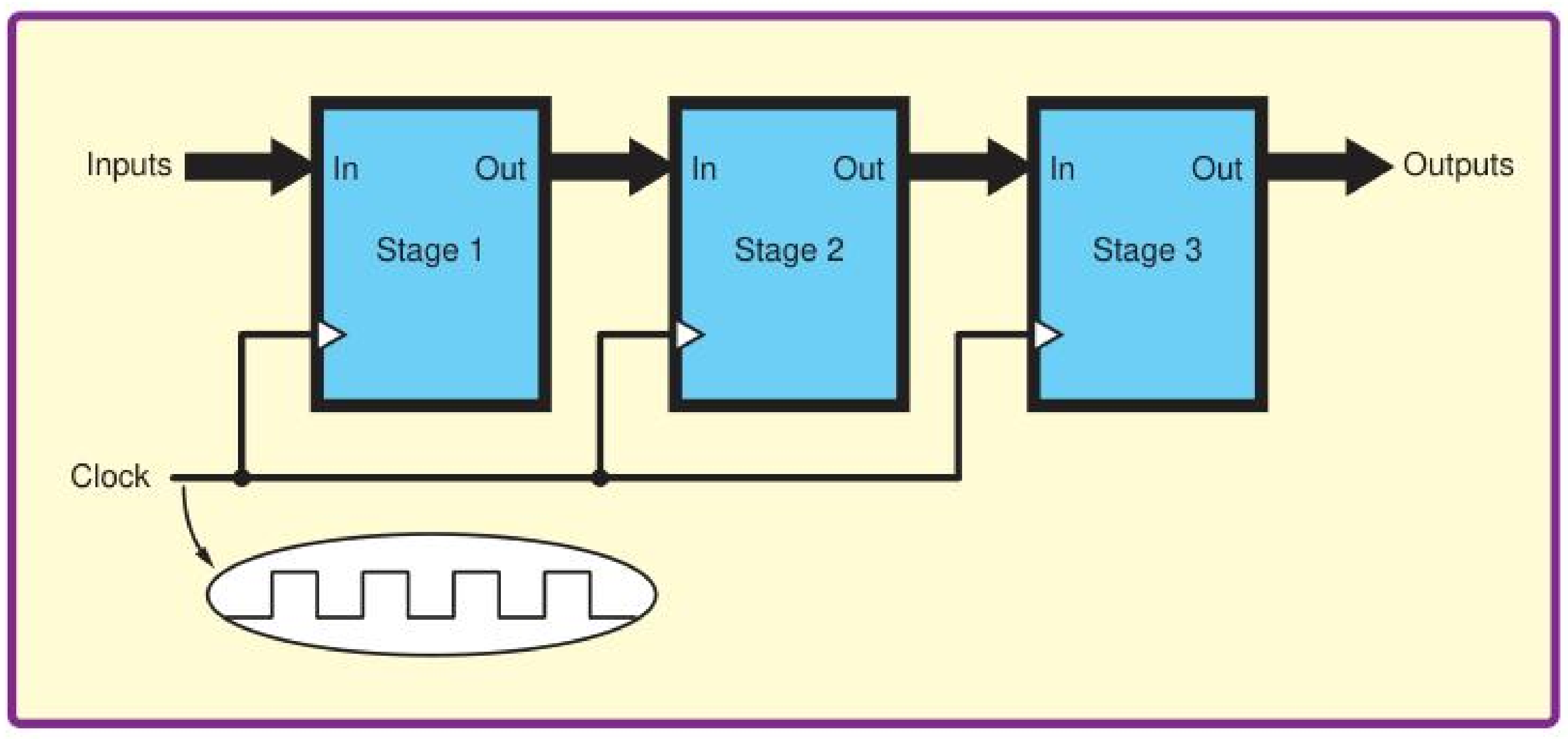


Fig.3. Multi-stage digital processing in a synchronous system

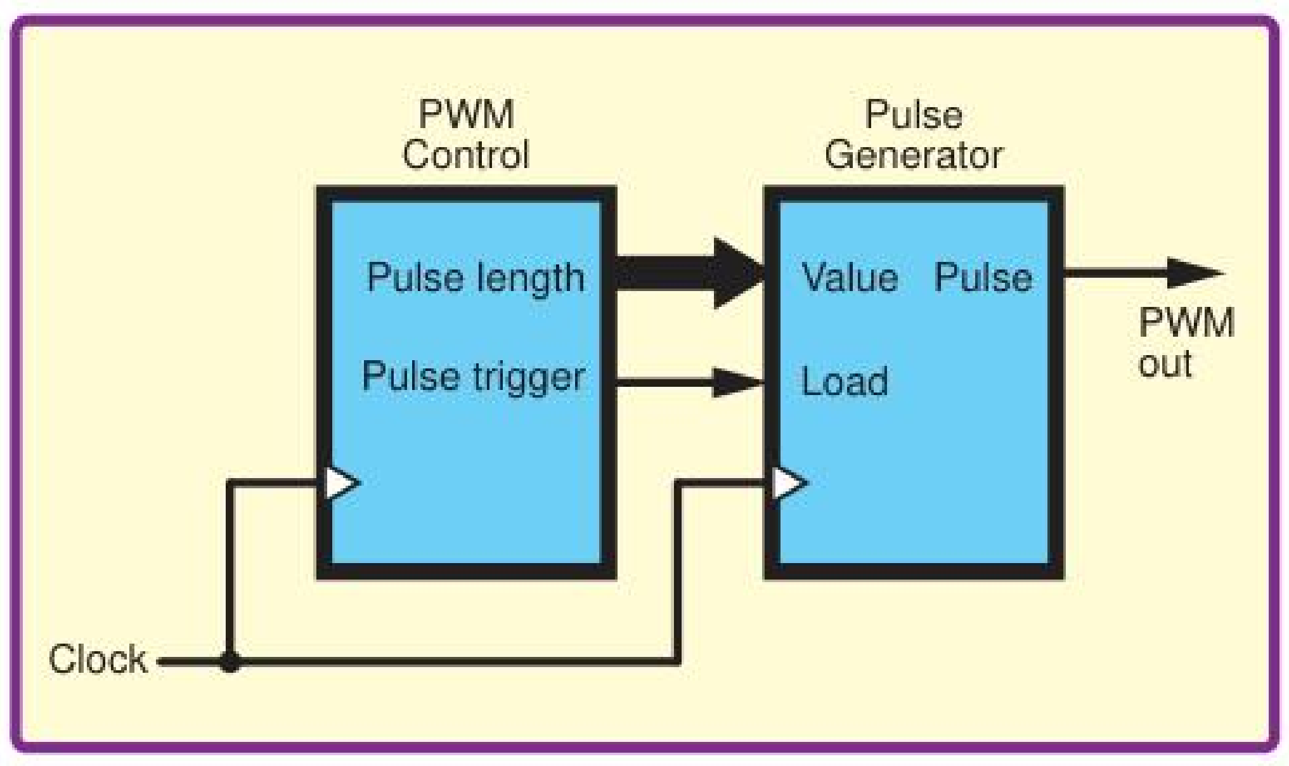


Fig.4. Two-stage synchronous digital system, structured like Fig.3, which uses the PWM generator from Fig.1 (reset not shown)

The stages (in Fig.3) operate simultaneously, so stage 1 is processing new data while stages 2 and 3 work on older information. This is a bit like an assembly line in a factory, where the finishing touches are applied to one copy of a product at the end of the line simultaneous with starting the production of another copy at the other end (and simultaneously with all the intermediate steps on other copies too). The clock sets the points in time when all 'items' (information) on the 'production line' move from the current stage to the next.

The structure of real circuits is often more complex than that shown in Fig.3, with feedback and feedforward of information, and multiple different paths through the system, rather than the simple 'straight through' structure depicted in Fig.3. However, Fig.3 is sufficient for our purpose of discussing the basics of timing in synchronous circuits.

Asynchronous

This article will only consider timing in synchronous circuits; however, before moving on to look at synchronous timing in more detail it is worth quickly mentioning that a multiple-step processing circuit like that in Fig.3 can be implemented asynchronously. A possible circuit structure is shown in Fig.6. Because there is no clock to initiate and coordinate the operation of each stage, the stages have to 'negotiate' with their neighbours when to transfer data, using some form of handshaking protocol. When the sending stage has data available, and the receiving stage is ready, data is transferred and processing progresses. Such circuits are potentially fast – they can act on new data immediately without waiting for the clock; and they are potentially power-efficient – they only perform processing when there is actually something to work on. However, they are more difficult to design and verify for correctness than synchronous circuits.

Returning to consider the circuit in Fig.3, we note that no electronic system is infinitely fast, so each stage takes some time to perform its operation, and each stage may take a different amount of time compared to other stages. Furthermore, the time used by a stage may vary with the data being processed. Until a stage has completed its work its outputs may be invalid and must not be used by the following stage. Given that all stages start working on new data together at the start of each clock cycle it follows that the clock cycle must be at least as long as the time taken by the slowest stage.

Structure

In order to consider the timing in more detail we need a slightly more detailed picture of the typical circuit structure

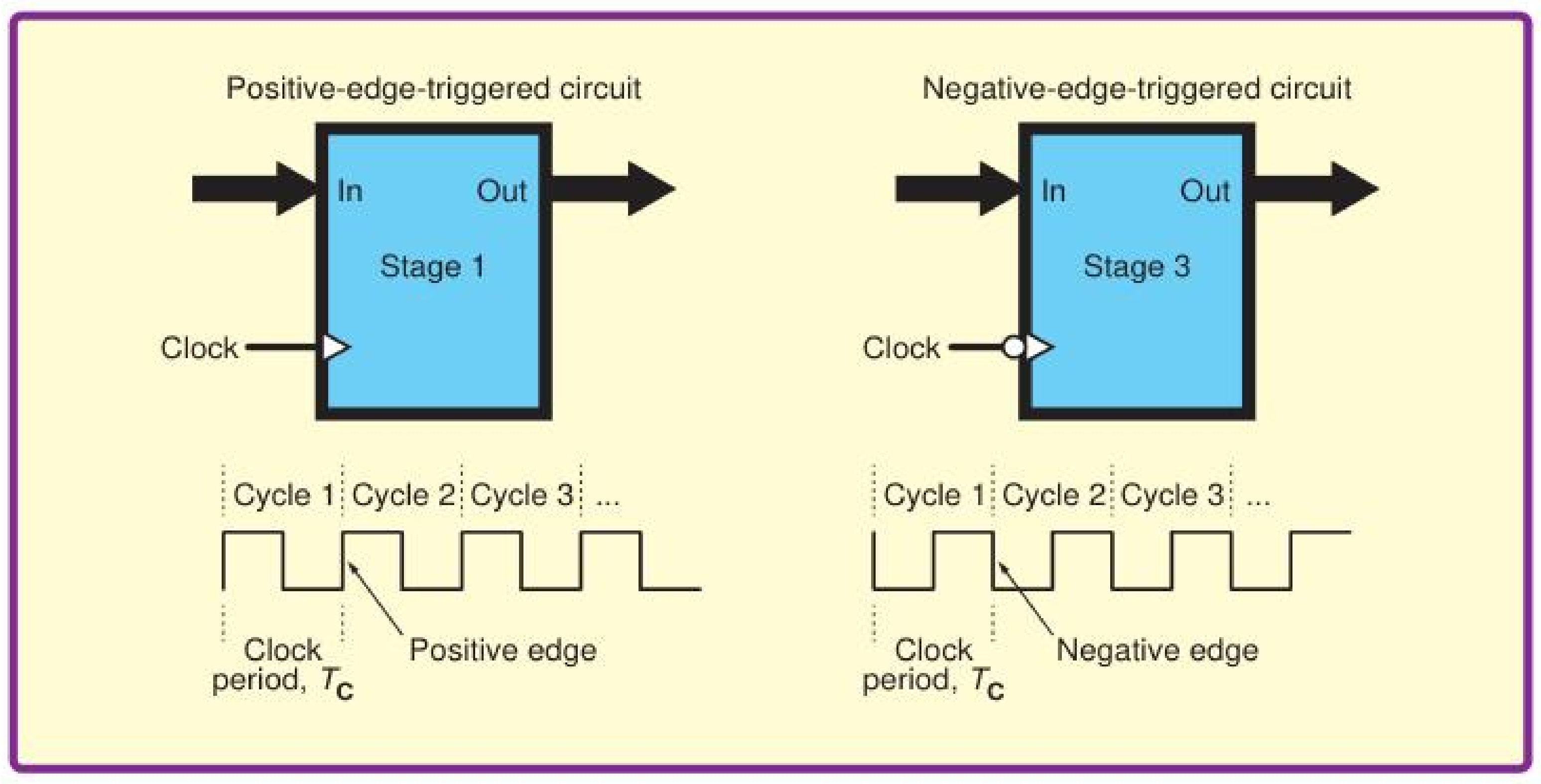


Fig.5. Some definitions relating to clocks

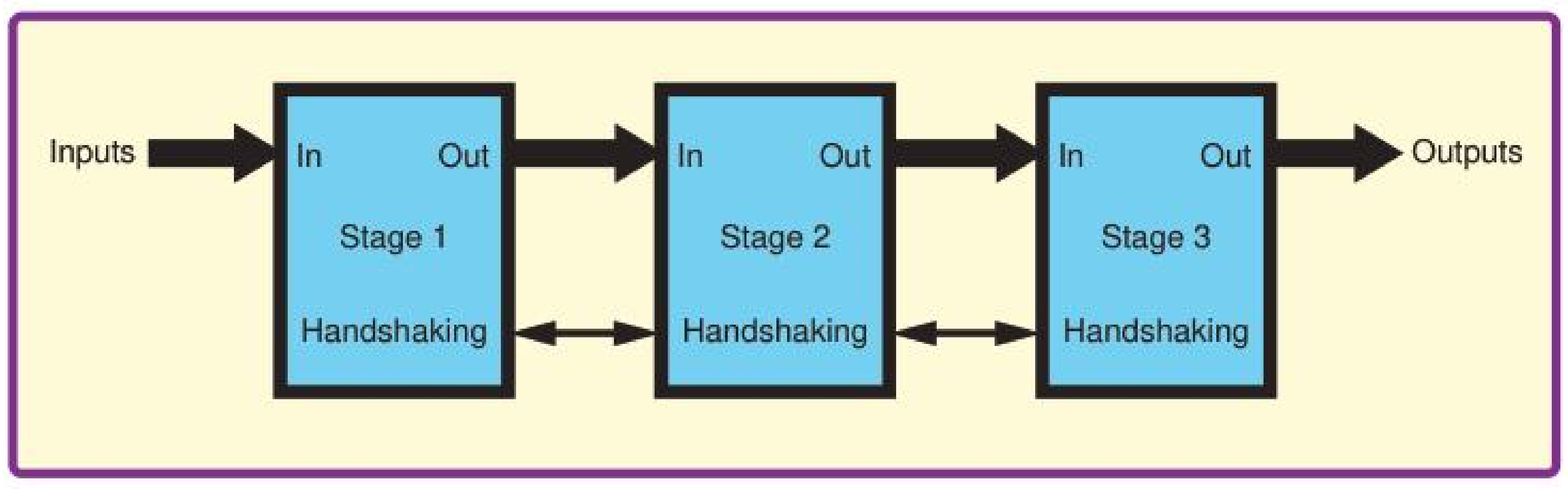


Fig.6. Multi-stage digital processing in an asynchronous system

than provided by Fig.3. Previously, we described each stage as performing an operation (eg, adding, decoding and many more possibilities). These operations are fundamentally performed by blocks of combinational logic. Combinational circuits do not contain any memory elements (flip-flops or latches) so their outputs depend only on the current value of their inputs. In a synchronous circuit the data being processed by any combinational circuit is held in a register connected to the combinational logic's inputs. A register is simply a collection of edge-triggered flip-flops, where each flip-flop stores one bit. This is illustrated in Fig.7, where register R1 holds the data being worked on by combinational logic CL.

For the circuit in Fig.7, when the active clock edge occurs, the register R1 loads new data. Specifically, the data on its D inputs is stored in the register and appears at its Q outputs. The register is not infinitely fast, so its outputs change a short time after the clock edge, this is referred to as the propagation delay of the register (we will call it T_{DR}). Given that the register is typically a set of identical flip-flops we can often assume that all its outputs update at more or less the same time.

Again, referring to Fig.7, when the register R1 updates the inputs to the combinational circuit change, then after some time its outputs will respond. Unlike the register, we cannot generally assume that all combinational logic outputs change at about the same time. In fact, each output bit may change several times, producing various intermediate output values for a while, until all the effects of the input change have propagated though and the circuit settles. These intermediate outputs are called 'hazards' or 'glitches'. In terms of timing, we are mainly interested in the longest possible time the combinational circuit will take to fully settle in response to any input change. This value is referred to as the 'propagation delay' of the circuit (we will call it T_{DCL}). Unless the circuit has been specifically designed to be guaranteed 'hazard-free', we generally have to assume that the outputs may change somewhat unpredictably from the moment any input changes until the propagation delay time has passed.

Combinational

Fig.8 shows three ways in which the response of a combinational logic circuit might be depicted on a timing diagram. An adder circuit is used as the example, but the same idea applies in other contexts. The first output waveform (a) shows the output changing after a certain delay. This is the simplest approach and is commonly used on datasheets and other situations where the overall function of the circuit containing the block of combinational logic is the main focus of discussion. If the overall circuit design ensures that any glitches that might be there cannot cause a problem then there is no need to complicate the diagram by showing them.

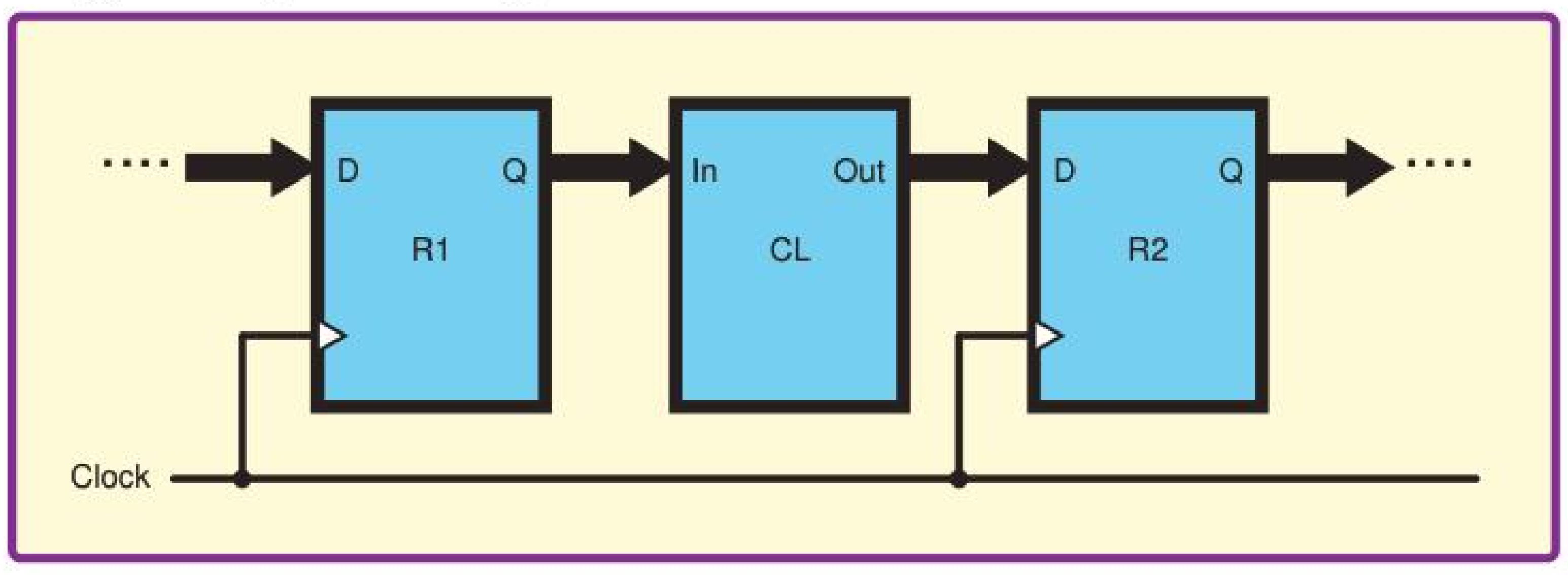


Fig.7. Register-to-register transfer (R1, R2) via a block of combinational logic (CL) is the key structure in a synchronous circuit

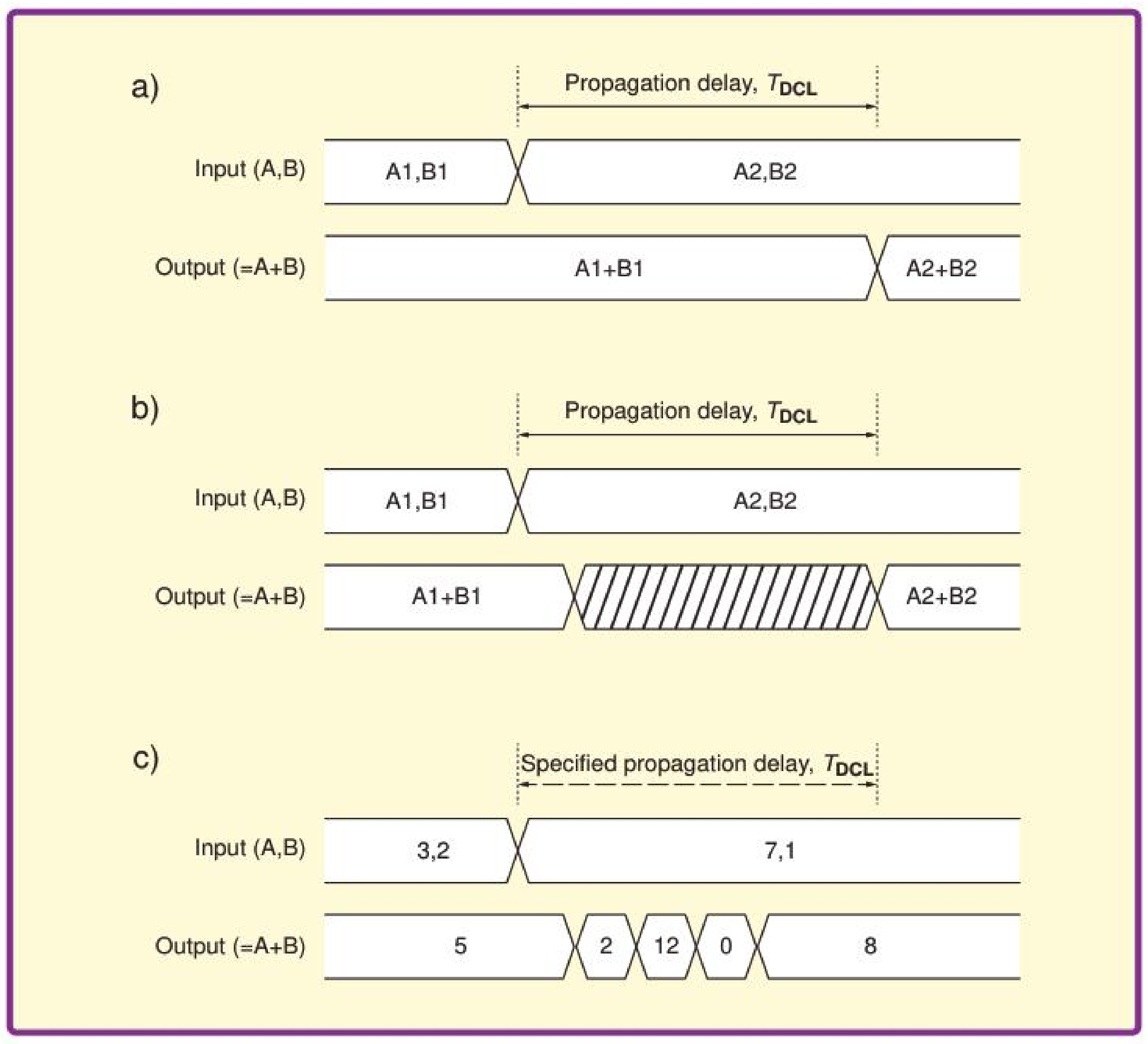


Fig.8. Example timing diagrams for a combinational logic circuit. the circuit adds two values A and B and outputs their sum A+B. a) Simple generic depiction of delay; b) Generic depiction of delay highlighting time during which correct output may not be available; c) Depiction of specific case with defined input values, specific intermediate outputs, and less than worst-case delay.

The second version of the combinational circuit output waveform in Fig.8 b) shows the period of uncertainty in the output value (where glitches might occur). Crosshatching is used here, but other graphical elements, including colour, could be used. This form of waveform is most likely to be used when discussing details of timing rather than function; for example, analysing the conditions under which a circuit might fail due to timing problems.

The third version of the combinational circuit output waveform in Fig.8 c) shows precisely what happens with a particular input change. Specific intermediate values and the times at which they change are depicted. This form of the waveform is most likely to be seen when using a logic simulator. A simulator can show exactly what happens when inputs change between particular values, but only if it is using a model or description of the circuit with sufficient detail of the implementation.

Period

Returning to Fig.7, we now know that after an active clock edge the outputs of register R1 will update after delay T_{DR} and the combinational logic will be outputting the final, stable, correct value after a further delay of T_{DCL}. On the next active clock edge the output of the combination logic will be loaded into register R2. It seems that as long as the clock period is greater than $T_{DR} + T_{DC}$ then R2 will load the correct value. In reality, the clock period has to be a bit longer than this because of the way R2 (or any register or flip-flop) responds to changes on its data input.

In a circuit in which information is fed back, R1 and R2 may be the same physical register. This does not change any of the arguments made here about timing. A counter circuit provides a typical example of fed-back data – the combinational logic takes the current count value, adds 1 to it and presents this to the input of the same register. At the clock edge the register loads its current value plus 1, thus incrementing the count.

An edge-triggered flip-flop only changes its output under the control of its clock input. Changes on the data input have no effect on the output if it is not clocked. However, data input changes do affect the internal circuitry. If the data changes, the flip-flop's internal circuitry takes time to settle in response to that change. If the clock is activated just after a data change, before the internal circuitry has settled, the flip-flop may not function correctly. It may load the wrong value or go into a 'halfway' state, outputting an invalid

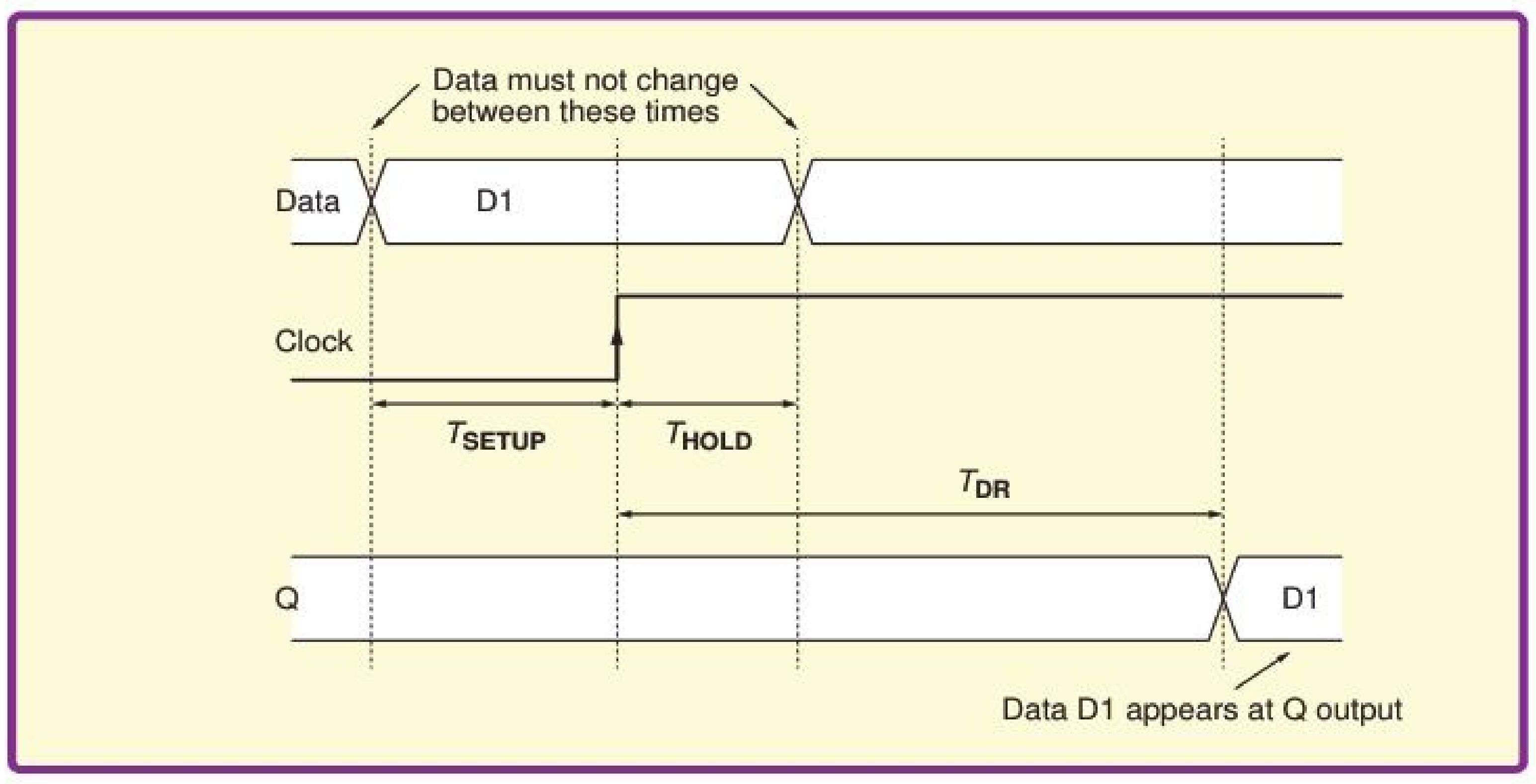

Data must not change between these times
Data
D1
Clock
T_{SETUP}
T_{HOLD}
T_{DR}
Q
D1
Data D1 appears at Q output

Fig.9. Definition of setup and hold time requirements

voltage (not 1 or 0) and stay like that for a comparatively long time, with respect to its normal response speed. This situation is called 'metastability' and is potentially catastrophic for a digital system.

Requirements

Flip-flops are specified in terms of the time that must pass after the data is changed before a clock is applied – this is called the setup time (T_{Setup}). Similarly, the data must not change for a certain time after the clock – this is the hold time (T_{hold}). Setup and hold times are illustrated in Fig.9. This timing diagram is for the purposes of defining timing parameters, it is not showing expected circuit operation. Normally, data changes would not be exactly on the setup and hold times, as that would be too risky.

Fig.10 shows the various delays associated with register-to-register transfer in a synchronous circuit. The minimum clock period must be greater than $T_{DR} + T_{DC} + T_{Setup}$ to make sure that the data loaded into R2 is valid. The behaviour of the combinational logic output / R2 input is shown in the same format as Fig.8 b). The combinational logic output must be guaranteed to settle before the setup time before the next active clock edge.

Scenarios

Running a circuit close to the maximum clock speed means that signals in the circuit change late in the clock cycle. If we are analysing the timing limitations of a circuit, then this is kind of scenario might be depicted in a timing diagram. However, if the aim of the timing diagram is to depict the basic function of the circuit, more conservative timing is likely to be shown. This is the case in Fig.2 – all the signals (load, value, Q and Pulse) are shown changing shortly after the active clock edge. Such functional timing diagrams are likely to use the format in Fig.8 a) for data signals. If the system is working well within its speed limits the intermediate outputs from combinational logic do not matter because they cannot end up being loaded into a register. Furthermore, the specific timing of signals between registers is not particularly important – signals can be shown changing an arbitrary short time after the clock edge to represent delay, but where the exact point the change is drawn is not particularly important. The inputs to the circuit in Fig.1 are shown on Fig.2 with timing that implies that they originate from another part of the same synchronous system (as in Fig.4) – it is the user's responsibility to ensure input timing is valid, so this is reasonable.

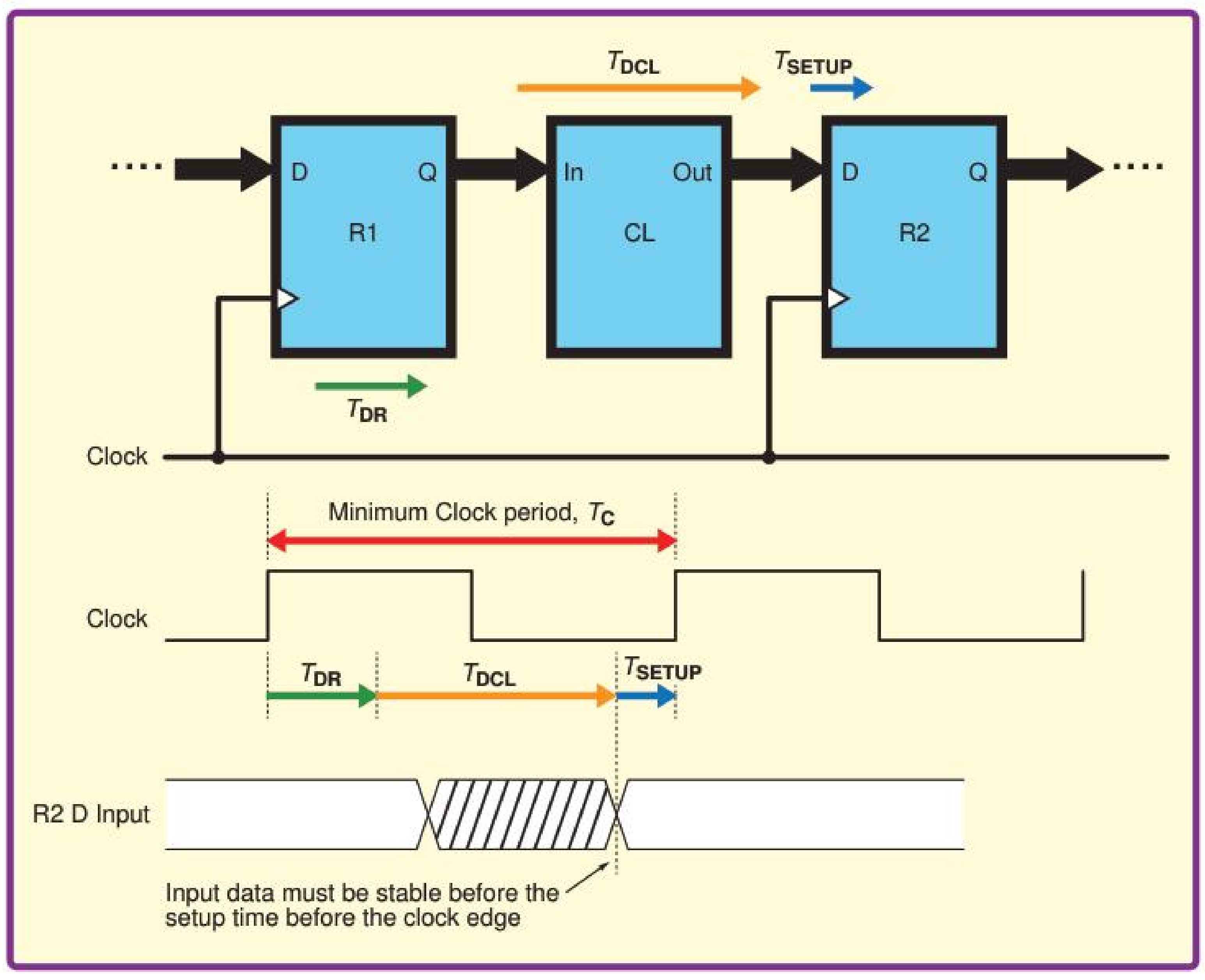

T_{DCL}
T_{SETUP}
D
Q
R1
In
Out
CL
D
Q
R2
T_{DR}
Clock
Minimum Clock period, T_C
Clock
T_{DR}
T_{DCL}
T_{SETUP}
R2 D Input
Input data must be stable before the setup time before the clock edge

Fig.10. Detailed timing for register-to-register transfers

WIN! New BeagleBone® Blue
From Farnell element14 (RRP £63.82 Exc VAT)

The latest offering from the BeagleBoard® range, has been built specifically for use in the development of robotics and autonomous vehicles.

Aimed at hardware and software engineers, makers and education markets, BeagleBone® Blue is built around the familiar BeagleBone® open-hardware computer. Its high-performance and flexible networking capabilities are coupled with a real-time capable Linux system and a set of peripherals suited for building mobile robots quickly and affordably; from precise motor control and feedback systems to rechargeable, portable power management.

The onboard 9-axis inertial measurement unit and barometer enable the development of self-aligning and orienting robotics, whether grounded or airborne, all directed with the support of on-board 802.11/b/g/n and Bluetooth 4.1/BLE wireless technology.

BeagleBone® Blue uses an Octavo Systems OSD3358 System-in-Package device, which includes a TI AM3358 1GHz ARM Cortex-A8 CPU with 512MB DDR3 RAM, 4GB 8-bit on-board Flash storage and power management. One of the key benefits of the TI AM3358 device is that it has two 32-bit programmable real-time units (PRUs) running at 200MHz, making BeagleBone® Blue ideally suited for robotics applications.

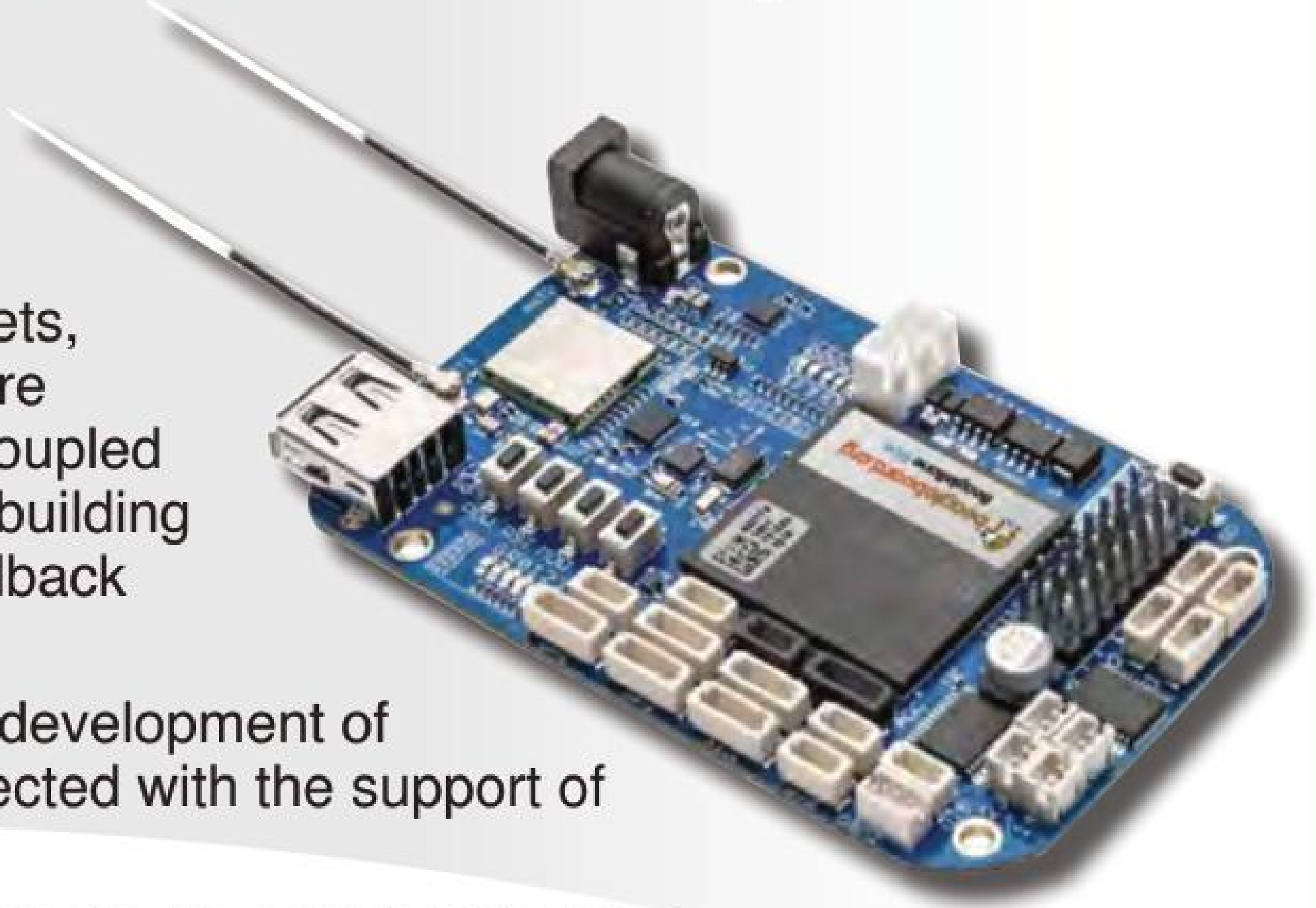
For your chance to win a BeagleBone® Blue, enter your details now!

HOW TO ENTER: visit **www.uk.farnell.com/epe-beagleboneblue** and enter your details

CLOSING DATE: 28 April 2017

beagleboard.org®

Farnell element14



BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past five years are available. An *EPE* index for the last five years is also available at **www.epemag.com**. Where we are unable to provide a back issue a photocopy of any one article (or one part of a series) can be purchased for the same price. Issues from Jan. 99 are available on CD-ROM or DVD-ROM – and back issues from recent years are also available to download from **www.epemag.com**. Please make sure all components are still available before commencing any project from a back-dated issue.

DID YOU MISS THESE?

BACK ISSUES ONLY £5.00 (each inc. UK p&p.)

Overseas prices £5.80 each surface mail, £6.80 each airmail.

We can also supply issues from years: 2006 (**except** Jan., Feb., Mar., Apr., May, July). 2007 (**except** June, July, Aug), 2008 (**except** Aug, Nov, Dec) 2009 (**except** Jan, Mar, Apr.). 2010 (**except** May, June, July, August, Oct, Nov, Dec) 2011 (**except** Jan) Jan 2014.

APR '16

PROJECTS • Appliance Insulation Tester • Low Frequency Distortion Analyser • Really Bright 12/24V LED Oyster Light •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 3 • Audio Out • Interface • Net Work • PIC n' Mix • Circuit Surgery • Electronic Building Blocks • Max's Cool Beans •

MAY '16

PROJECTS • 2-Channel Balanced Input Attenuator For Audio And Digital Scopes • Appliance Leakage Tester • 4-Output Universal Voltage Regulator •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 4 • Practically Speaking • Net Work • PIC n' Mix • Circuit Surgery • Electronic Building Blocks • Max's Cool Beans •

JUN '16

PROJECTS • The Bad Vibes Infrasound Snooper • Audio Signal Injector And Tracer • Champion Preamp •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 5 • Interface • Net Work • PIC n' Mix • Circuit Surgery • Electronic Building Blocks • Max's Cool Beans • Audio Out • Alan Sugar Autobiography Review

JULY '16

PROJECTS • Driveway Monitor – Part 1 • Intelligent Charger For Nicad And NiMH Batteries • Install USB Charging Points In Your Car •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 6 • Practically Speaking • Net Work • PIC n' Mix • Circuit Surgery • Electronic Building Blocks • Max's Hot Beans •

AUG '16

PROJECTS • Low-Cost, Accurate Voltage/Current/Resistance Reference • Checking And Calibrating Multimeters • Driveway Monitor – Part 2 • USB Power Monitor •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 7 • Interface • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Max's Cool Beans •

SEPT '16

PROJECTS • Compact Hybrid Switchmode 100W Bench Supply – Part 1 • Speedo Corrector – Mk.3 • LED Party Strobe •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 8 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Max's Hot Beans • Electronic Building Blocks •

OCT '16

PROJECTS • Arduino-Based USB Electrocardiogram • 5-Element Yagi Antenna • Compact Hybrid Switchmode 100W Bench Supply – Part 2 •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 9 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Practically Speaking •

NOV '16

PROJECTS • Fingerprint Access Controller • Cheap Programmer For The PIC32 Microcontroller • Compact Hybrid Switchmode 100W Bench Supply – Part 3 • Ingenuity Unlimited •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 10 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Interface • Max's Hot Beans •

DEC '16

PROJECTS • Universal Loudspeaker Protector • 9-Channel Infrared Remote Control • Revised USB Charger Regulator With Low Battery Cut-Out •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 11 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Max's Hot Beans •

JAN '17

PROJECTS • High-Performance Stereo Valve Preamplifier – Part 1 • High Visibility 6-Digit LED GPS Clock – Part 1 • 5-Element Yagi Specifically For DAB Radio •

FEATURES • Techno Talk • Teach-In 2016 – Exploring The Arduino – Part 12 • Interface • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Max's Hot Beans •

FEB '17

PROJECTS • Solar MPPT Charger And Lighting Controller – Part 1 • Check Your Turntable's Speed With This White LED Strobe • High-Performance Stereo Valve Preamplifier – Part 2 • High Visibility 6-Digit LED GPS Clock – Part 2 •

FEATURES • Techno Talk • Meet The Mighty Micromite – Part 1 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Max's Cool Beans •

MAR '17

PROJECTS • Speech Timer For Contests & Debates • Solar MPPT Charger And Lighting Controller – Part 2 • Arduino-Based Fridge Monitor And Data Logger • High Visibility 6-Digit LED GPS Clock – Part 2 • Ingenuity Unlimited •

FEATURES • Techno Talk • Meet The Mighty Micromite – Part 2 • Net Work • PIC n' Mix • Circuit Surgery • *EPE* Product Review – LabNation SmartScope • Interface • Electronic Building Blocks • Max's Cool Beans •

APR '17

PROJECTS • Microwave Leakage Detector • Arduino Multifunction 24-Bit Measuring Shield • Battery Pack Cell Balancer • Ingenuity Unlimited •

FEATURES • Techno Talk • Meet The Mighty Micromite – Part 3 • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Electronic Building Blocks • Max's Cool Beans •

ORDER FORM – BACK ISSUES – PHOTOCOPIES– INDEXES

☐ Send back issues dated. . . . .

☐ Send photocopies of (article title and issue date) . . . .

Name . . . .

Address. . . . .

. . . . .Tel: . . . .

☐ I enclose cheque/P.O./bank draft to the value of £ . . . .

☐ Please charge my Visa/Mastercard/Maestro £ . . . .

Card No . . . .

Valid From . . . . Card Expiry Date . . . . Card Security Code . . . .
(The last 3 digits on or just under the signature strip)

SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.**
Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk **On-line Shop**: www.epemag.com

Payments must be in £ sterling – cheque or bank draft drawn on a UK bank. Normally posted within seven days of receipt of order. Send a copy of this form, or order by letter if you do not wish to cut your issue.

M05/17

AUDIO OUT

By Jake Rothman

MX50 power amplifier kit – Part 1

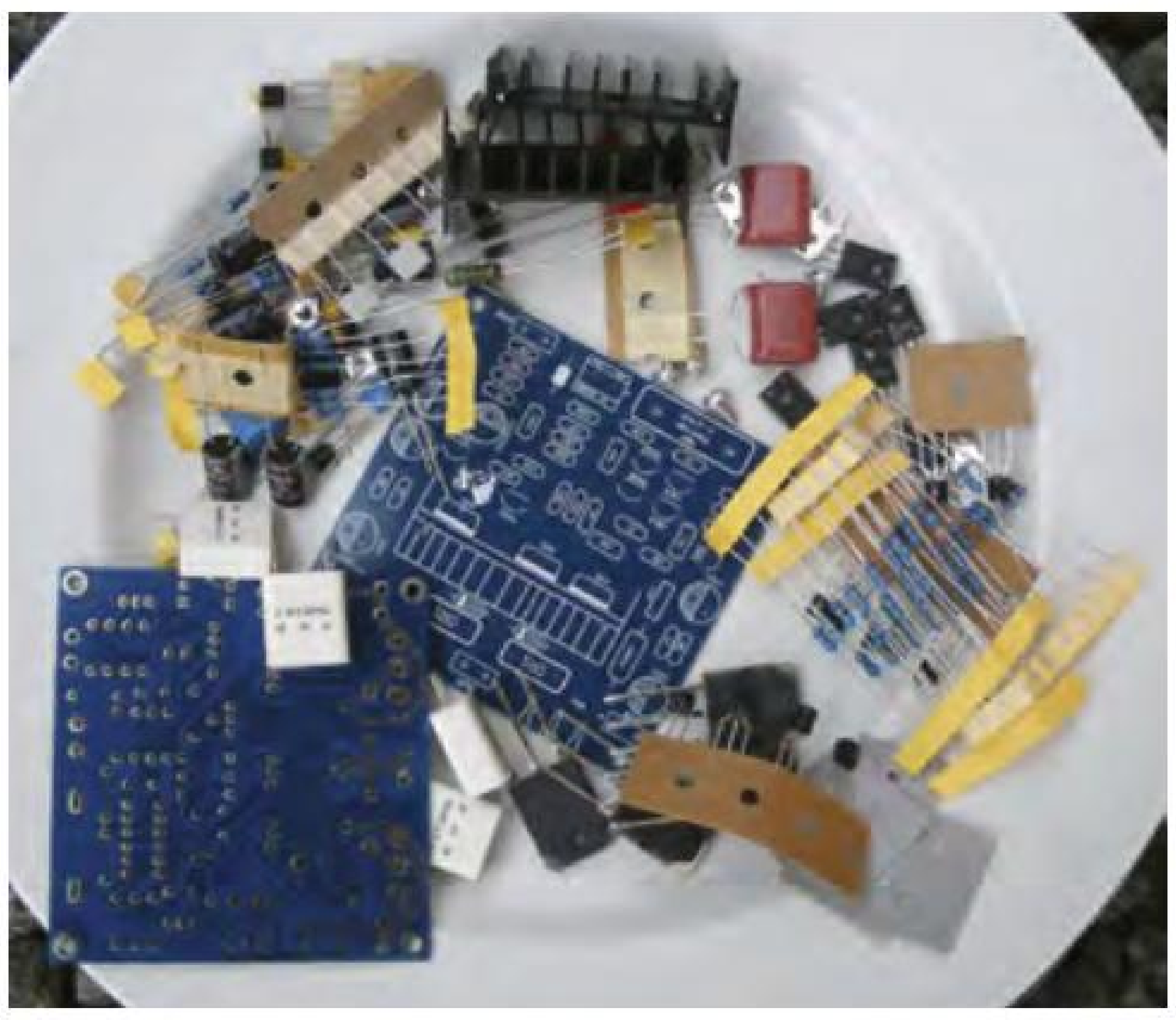
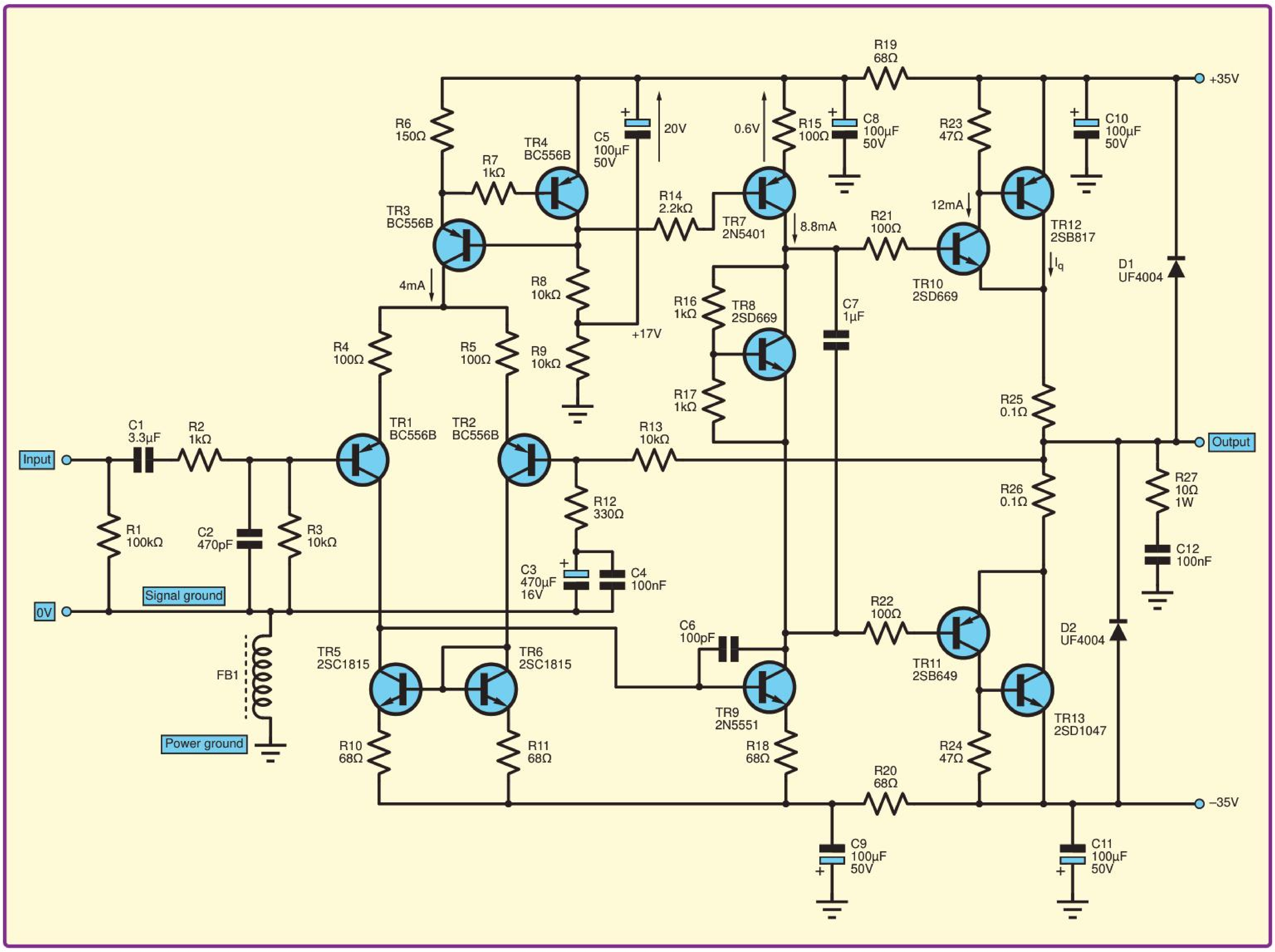


Fig.1. The MX50 kit – a lot of components for very little money.

Every so often, a bargain comes up online that's irresistible. This 50W stereo amplifier lets you make a posh power-amp for peanuts! It is advertised on eBay as the 'Douk Audio MX50 SE Dual 2.0 Channel Power amplifier Kit for DIY' from the seller Doukmall. The cost is £11.00 plus £2.99 postage. (There are other sources selling at higher prices, around £16.00.) I estimate this kit would cost at least £35 from normal UK suppliers. The catch is that the kit is just a bag of bits from Shenzhen, China (see Fig.1). There's no documentation, not even a circuit diagram, so you've got to know what you are doing. However, the design, PCBs and components are of such excellent quality, that the editor and I decided it was worth reverse engineering the design. This enabled the missing documentation to be generated so it could be easily built, even if the kits on eBay run out.

As an addition to my previous series on amplifier power supplies, we will use this module to show how to construct a stereo amplifier and dual-rail power supply for minimum distortion and noise.



R19
68Ω
+35V
R6
150Ω
TR4
BC556B
C5
100µF
50V
20V
0.6V
R15
100Ω
C8
100µF
50V
R23
47Ω
C10
100µF
50V
R7
1kΩ
R14
2.2kΩ
TR7
2N5401
8.8mA
R21
100Ω
12mA
TR12
2SB817
TR3
BC556B
Iq
D1
UF4004
TR10
2SD669
4mA
R8
10kΩ
R16
1kΩ
TR8
2SD669
C7
1µF
+17V
R4
100Ω
R5
100Ω
R9
10kΩ
R17
1kΩ
R25
0.1Ω
C1
3.3µF
R2
1kΩ
TR1
BC556B
TR2
BC556B
R13
10kΩ
Input
Output
R26
0.1Ω
R27
10Ω
1W
R1
100kΩ
C2
470pF
R3
10kΩ
R12
330Ω
C12
100nF
C3
470µF
16V
C4
100nF
Signal ground
0V
R22
100Ω
C6
100pF
TR5
2SC1815
TR6
2SC1815
D2
UF4004
TR11
2SB649
FB1
TR9
2N5551
TR13
2SD1047
Power ground
R10
68Ω
R11
68Ω
R18
68Ω
R24
47Ω
R20
68Ω
–35V
C9
100µF
50V
C11
100µF
50V

Fig.2. The MX50 circuit – another Douglas Self inspired design.

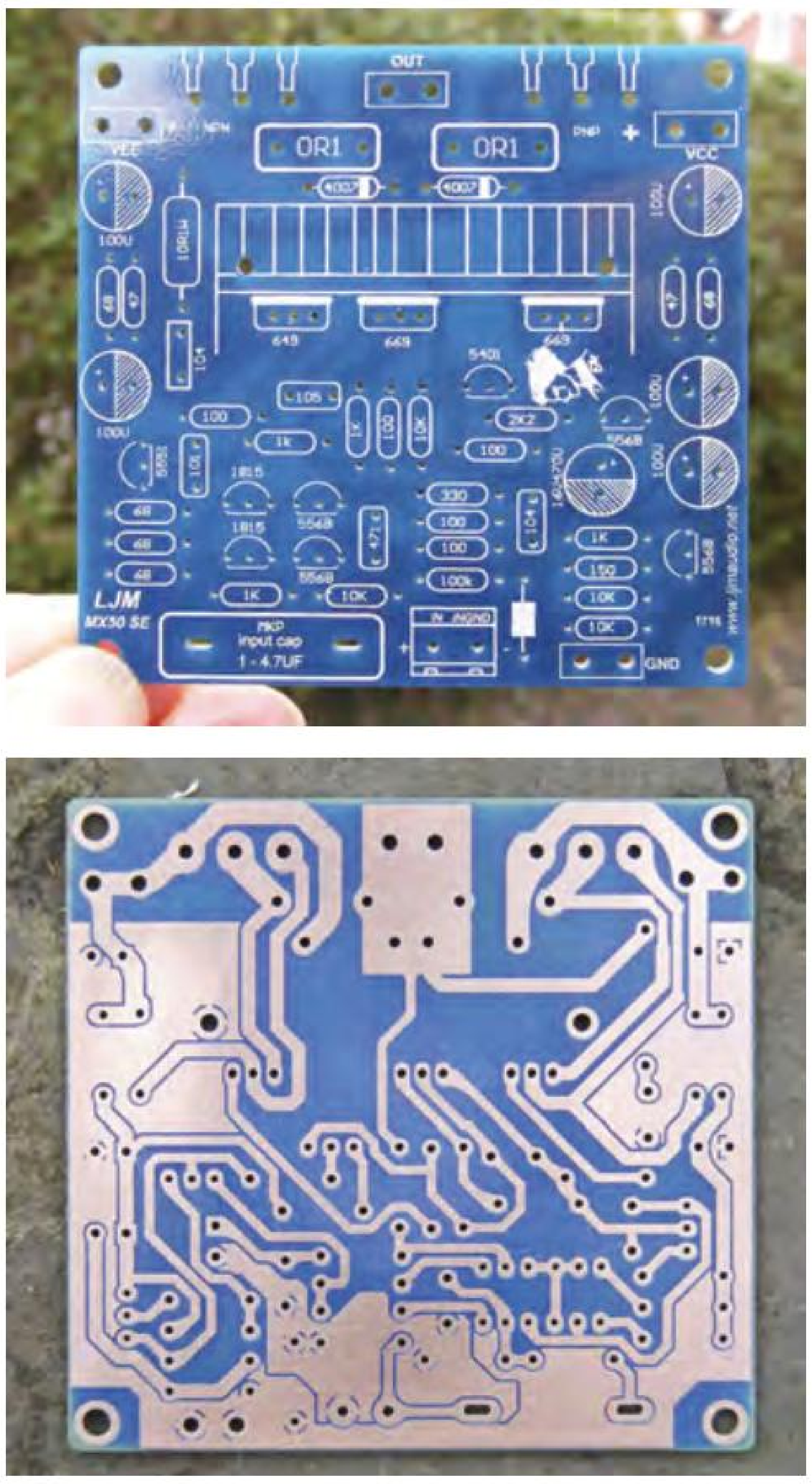


Fig.3 a) (top) The MX50 PCB, as supplied with component values, and b) (bottom) PCB track layout revealed after sanding.

Circuit

The circuit is clearly based on Douglas Self's Blameless 50W amplifier design, described in his *Audio Power Amplifier Design Handbook*, a distillation of years of research into the distortion mechanisms of the standard Lin circuit. Just like Baxandall and his tone control design, Self would have become rich if all amplifier manufacturers using his circuitry had paid him a small royalty. There are a few simplifications to his design (see the MX50 circuit in Fig.2) possibly to avoid copyright infringement. The main change being the omission of a buffer stage between the long-tailed pair (LTS) input stage and the voltage amplifier stage (VAS). This will make the distortion a bit higher. This is likely to be audibly insignificant because input stage distortion is subjectively much more benign than output stage distortion. Instead of an emitter-follower (EF) output stage, a complementary follower pair (CFP) stage is used. This configuration has slightly lower measured THD, but the distortion residue usually exhibits sharper spikes than the EF version, which may be more dissonant. The CFP stage does make the kit easier to build, because the temperature sensing V_{be} multiplier bias transistor can be mounted on the driver transistor heatsink on the board, rather than on the main output transistors.

The circuit has no quiescent current adjustment, just a 1kΩ resistor (R17) which gives a current that is safe at 10mA, but too low to be optimum. The driver transistor collector-load resistors, R23 and R24 are 47Ω rather than the normal 100Ω, which increases the driver dissipation, but this may give faster turn-off of the output devices. The lower-arm feedback capacitor (C3) is bypassed by a film capacitor (C4). This audiophile tweak was shown to be ineffective by the late Cyril Bateman. A couple of ultra-fast diodes (D1 and D2) have been placed across the supply rails to protect the output transistors from potentially damaging back EMFs from the speaker.

Short circuit

Do note that there's no short-circuit protection on this module; a possibly dangerous omission. One touch of the speaker leads, and bang! Possibly, this module is designed for use in active speakers where this should not happen, but it could happen in testing. I came across an active PA speaker where the aluminium wire voice-coil in the woofer had rubbed against the pole piece, causing a melted short-circuited voice-coil. I thought it could never happen! I've never seen it with a copper wire voice-coil though.

Hi-Fi designers often say no protection sounds better, but try telling that to a studio owner who's turning clients away because his monitoring system is burnt out. Adding short circuit protection is complex, involving a dozen components. Fuses will protect the transformer, PCB and most speakers, but bipolar transistor failure is much quicker and they usually blow before the fuses.

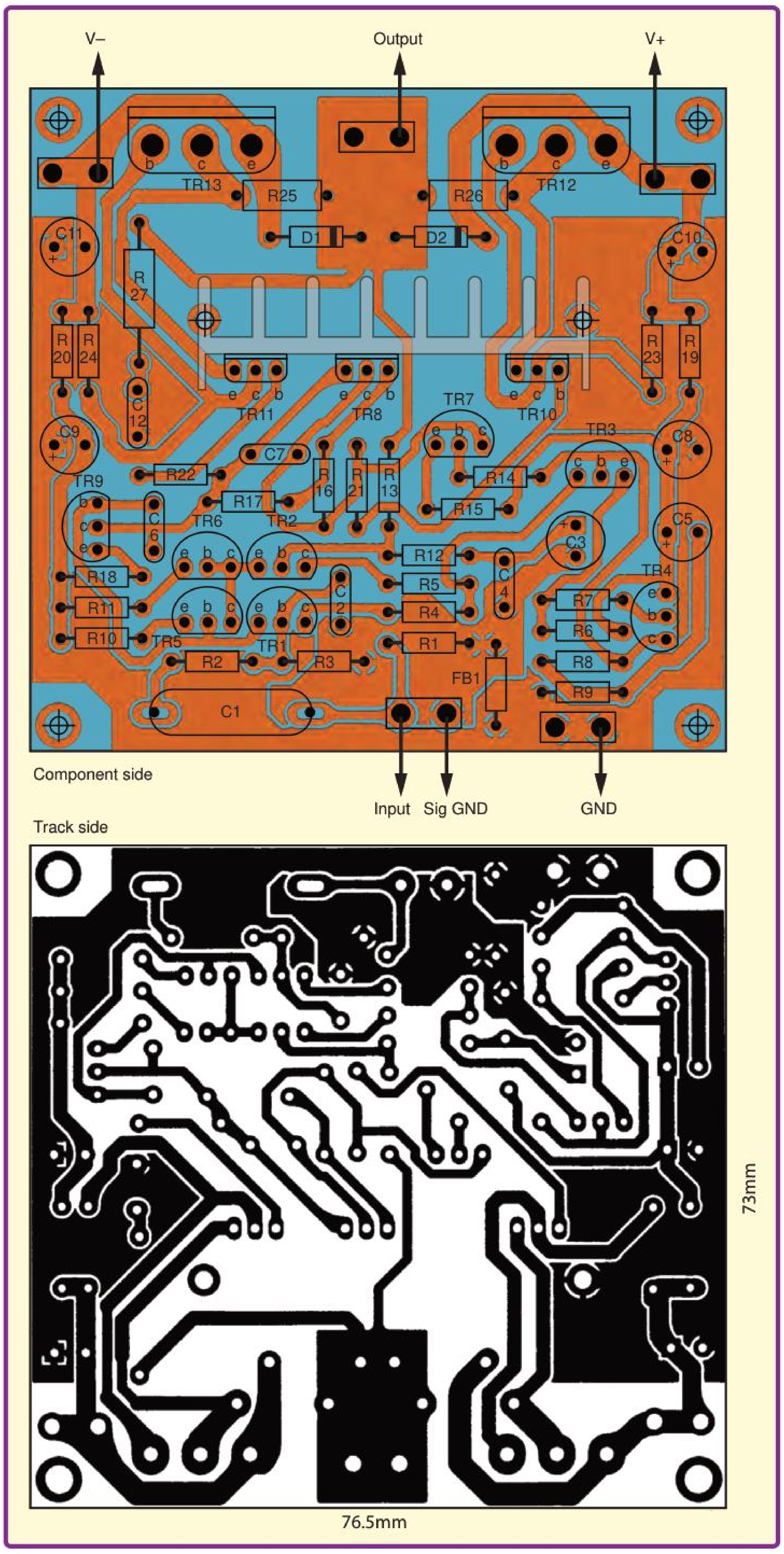


Fig.4 PCB overlay with component positions

Parts

Occasionally counterfeit parts are a problem with these sort of kits, but not here. The 140V 12A 100W output transistors are the proper KEC (Korean Electronics Company) devices derived from original Sanyo and Toshiba designs. I have never had any problems with KEC transistors, which I generally buy from Tayda. The electrolytic capacitors are Rubycon and Nippon Chemicon and all the other bits were fine. The PCB is a standard industrial-grade fibre glass, single-sided product of particularly neat and compact design with all the values clearly and accurately marked (see Fig.3a). It would be possible to build the amp from this information alone, which is the intention. I sanded off the blue silkscreen and solder resist on both sides (Fig.3a and 3b) to obtain the track

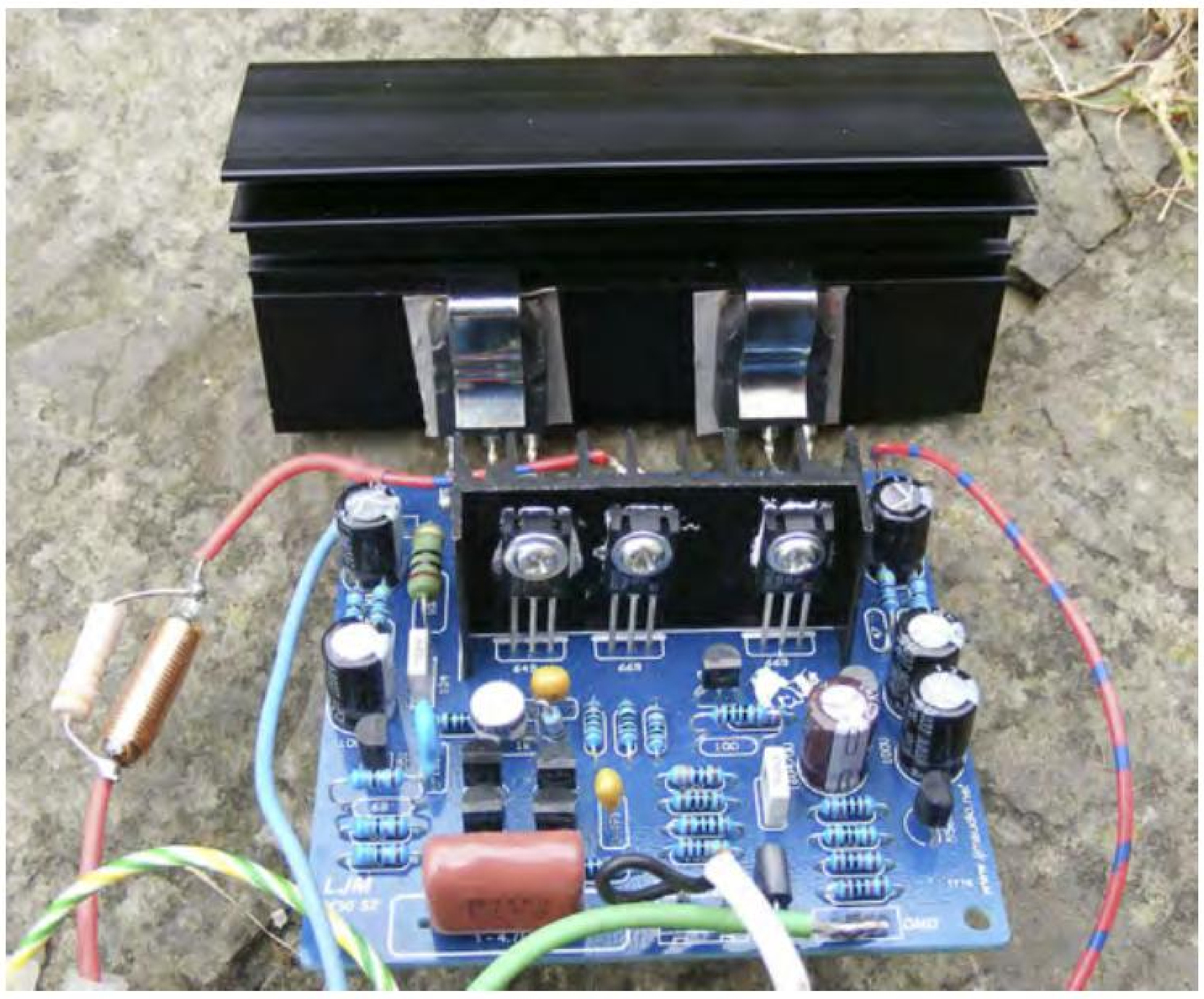


Fig.5. For low-power, a Rapid 3.3°C/W heatsink with clips suffices.

layout, which is shown in Fig.4. This was also necessary to trace the circuit diagram, since those circulating on the web have errors.

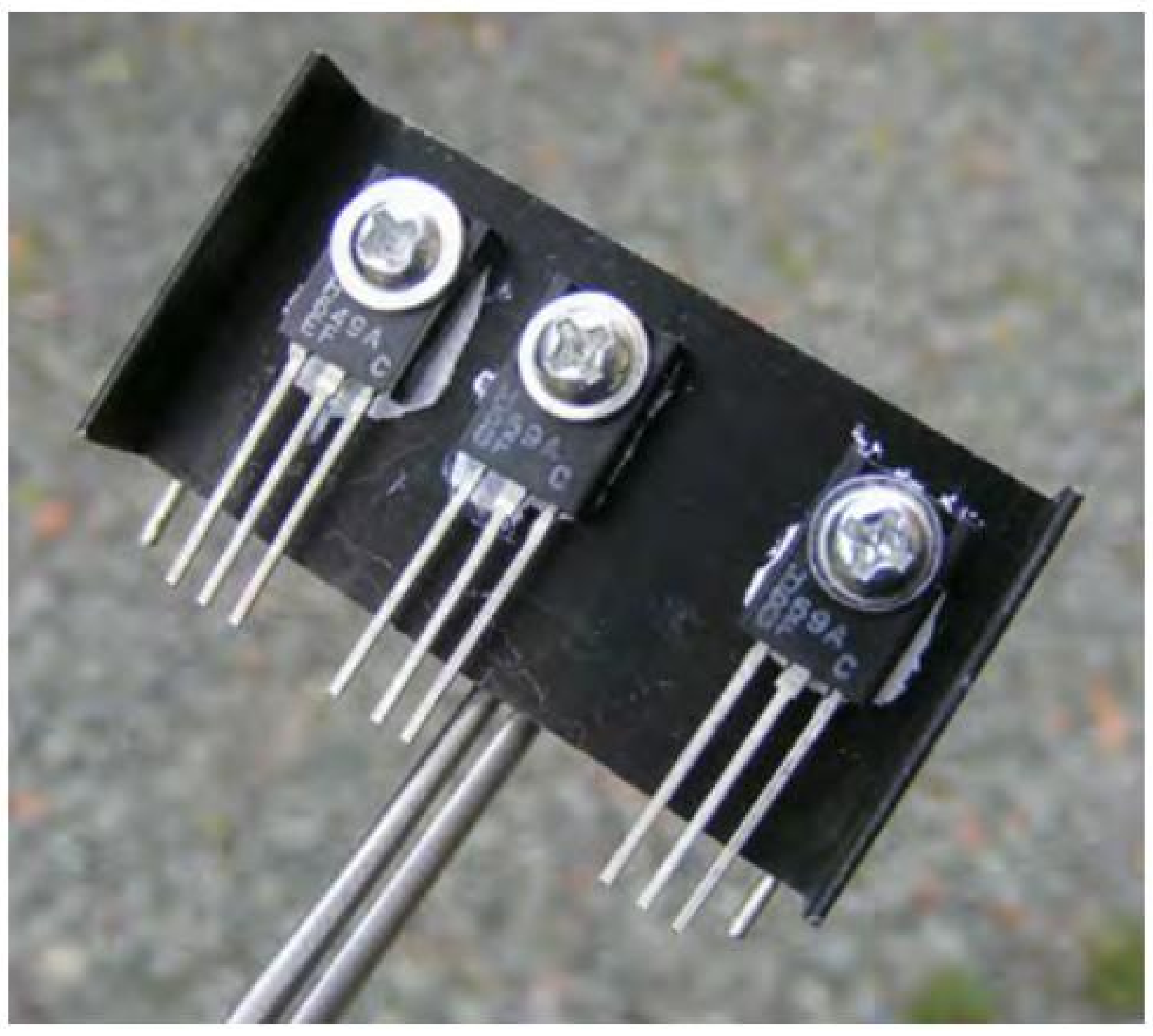


Fig.6. The driver transistors and bias transistor are mounted on a special small heatsink, which will be soldered to the PCB.

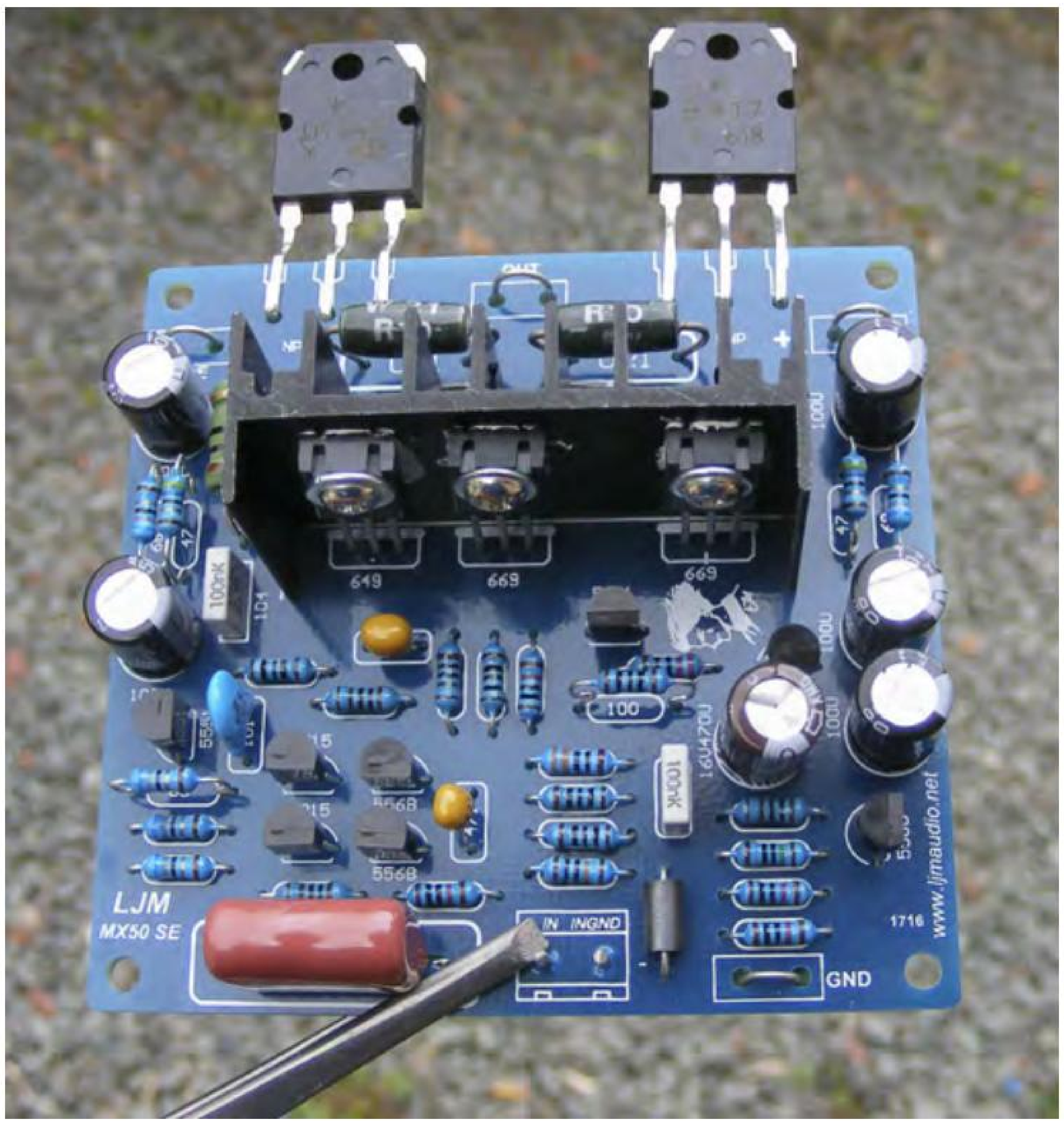


Fig.7. (right) The finished MX50 PCB.

Assembly

As with all amplifier modules, a heatsink and mains transformer are not included and must be provided by constructors. In the spirit of economy, these can be obtained cheaply from radio rallies and scrapped old amps, since they don't wear out (they are expensive if bought new from UK distributors). The ideal heatsink would be 1°C/W if continuous high power is needed. For Hi-Fi use at moderate volumes, it can be quite a bit smaller, such as the 3.3°C/W unit shown in Fig.5. Mica washers and heatsink compound will be needed, I find this messy but much more effective than the silicone rubber washers provided. The driver heatsink is a special item which will have to be replaced by a strip of aluminium or copper if not available. Remember to mount the heatsink and tighten the transistor mounting screws *before* soldering to prevent stress on the joints, as shown in Fig.6. No insulating washers are needed with the fully insulated transistors supplied, although a bit of heatsink compound is necessary. Spade terminals were provided, but these were too loose a fit on the board and replaced with wire loops. The emitter resistors R25 and R26 are the radial-mount ceramic-box type. These cannot be inserted fully because diodes D1 and D2 get in the way. The solution is to insert the two together and push the diodes over before soldering. A close-up of the finished PCB is shown in Fig.7.

Next month

In *Part 2*, next month, I will move on to consider the power supply and wiring, various potential improvements and explain how to test the finished amplifier.

PoLabs

For more information or software download please visit

www.poscope.com/epe

PoKeys
Connect, Control

- USB
- Ethernet
- Web server
- Modbus
- CNC (Mach3/4)
- IO
- PWM
- Encoders
- LCD
- Analog inputs
- Compact PLC

Stepper motor drivers
Drive

- up to 256 microsteps
- 50 V / 6 A
- USB configuration
- Isolated
- up to 32 microsteps
- 30 V / 2.5 A

PoScope Mega1+
PoScope Mega50
Measure

- up to 50MS/s
- resolution up to 12bit
- Lowest power consumption
- Smallest and lightest
- 7 in 1: Oscilloscope, FFT, X/Y, Recorder, Logic Analyzer, Protocol decoder, Signal generator

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

atlas LCR
LCR40
inductors
capacitors
resistors
passive component analyser
PEAK
on - test
scroll - off

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

★ LETTER OF THE MONTH ★

Digi-Clock reborn

Dear editor

A relative recently asked me if I still possessed the digital clock I built many years ago, having shown me an article describing a growing market in retro Nixie-tube clocks. I said that I did, but it was in very poor condition, languishing unused in my garage for a number of years.

I built the *Practical Electronics Digi-Clock* (*PE*, Dec 1970 – Mar 1971) as a post-apprenticeship project while serving in the Royal Navy. In hindsight, I don't think I could have completed it without access to the workshop facilities and test equipment available at the time.

The clock performed faultlessly for many years as a bedside alarm until sometime in the early 1980s when the alarm became unreliable and the sound muted. The clock timekeeping was perfect unless there was a power outage, but the whole thing was decidedly dated. It went to spend some years in the loft, and it was only after a major clearing session around 10 years ago that the clock was brought back into the world and sat on a shelf in my garage as a sentimental curiosity.

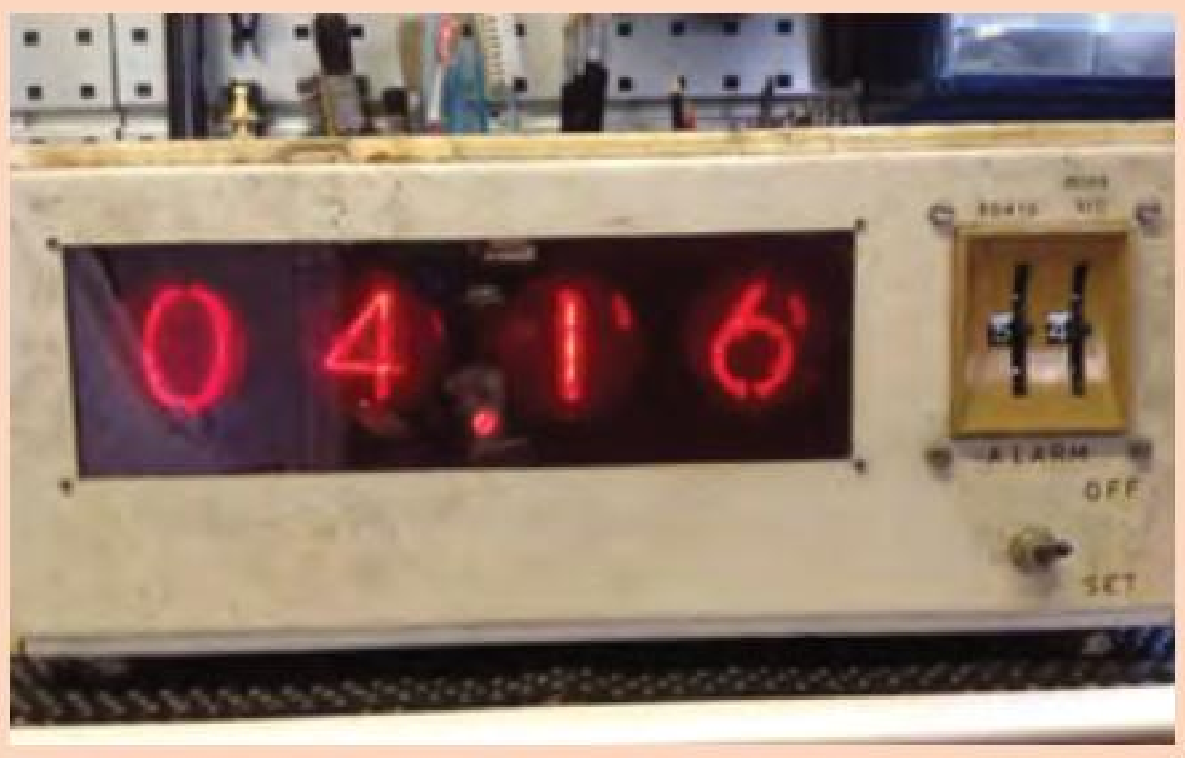
Motivated by the article I had been shown, coupled with a realisation that Nixie-tube-based equipment was now quite unusual, I resolved to repair and clean the now much-loved *Digi-Clock*. What started as a suspected simple alarm comparator circuit fault and general clean up, turned into a more complex repair and general overhaul. At this point it became clear that I had lost the original copies of *Practical Electronics*, which led me to the *EPE Chat Zone*. Fortunately, one of the members, Thomas Stratford, supplied copies of the relevant articles and I began the process of refurbishment:

- Intermittent operation of alarm BCD thumbwheel switches
- Failure of alarm oscillator circuit
- Inoperative decimal point neon
- General degradation of the case
- Discolouration of alarm time setting switches
- Degradation of Nixie tubes external mask coating

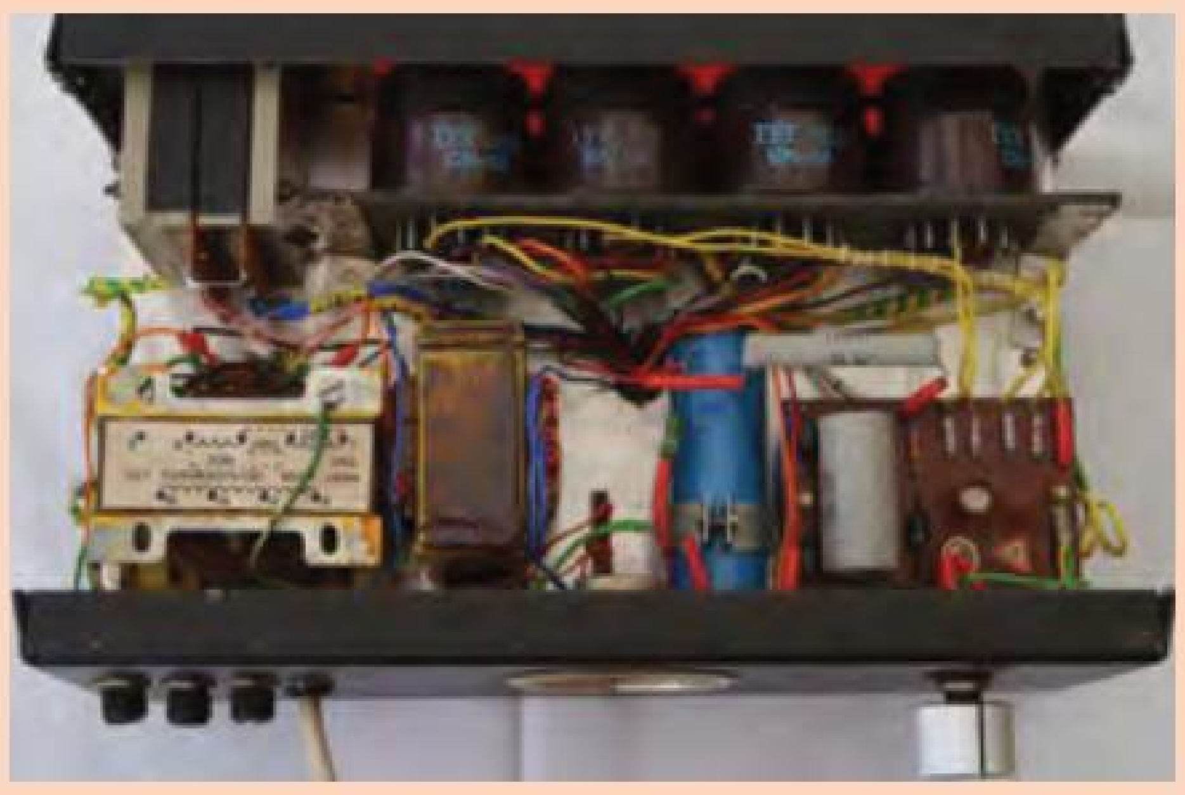
The BCD switches had to be completely disassembled in order to clean the wipers and contact surfaces. This entailed removing the plastic welds holding each thumbwheel assembly and then securing the reassembled switch with small bolts. The alarm oscillator failure turned out to be a simple dry joint. A replacement decimal point neon indicator was fitted, the case and BCD switches externally repainted and new masking fitted around the Nixie tubes. The results can be seen in the accompanying photos. My thanks must go to all at the *EPE Chat Zone* who helped, especially Thomas Stratford.

David Hull, by email

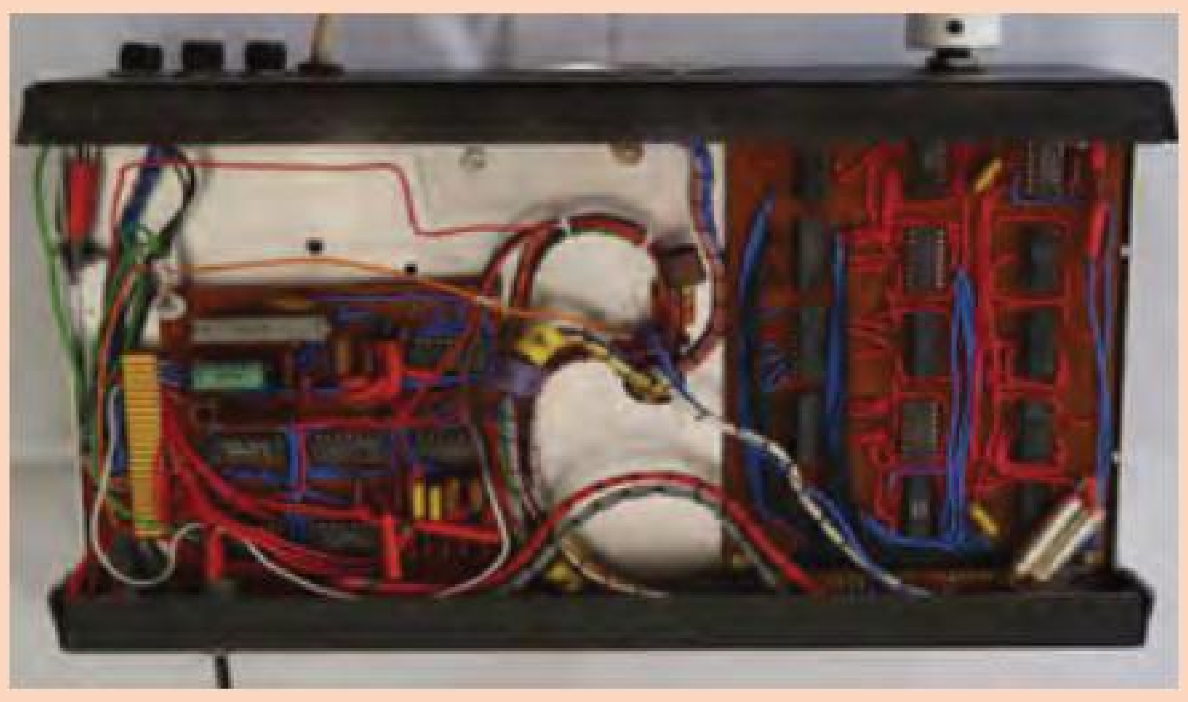
Matt Pulzer replies
Marvellous work David – a real tribute to the original project's design and your skill in first building and then refurbishing the Digi-Clock.



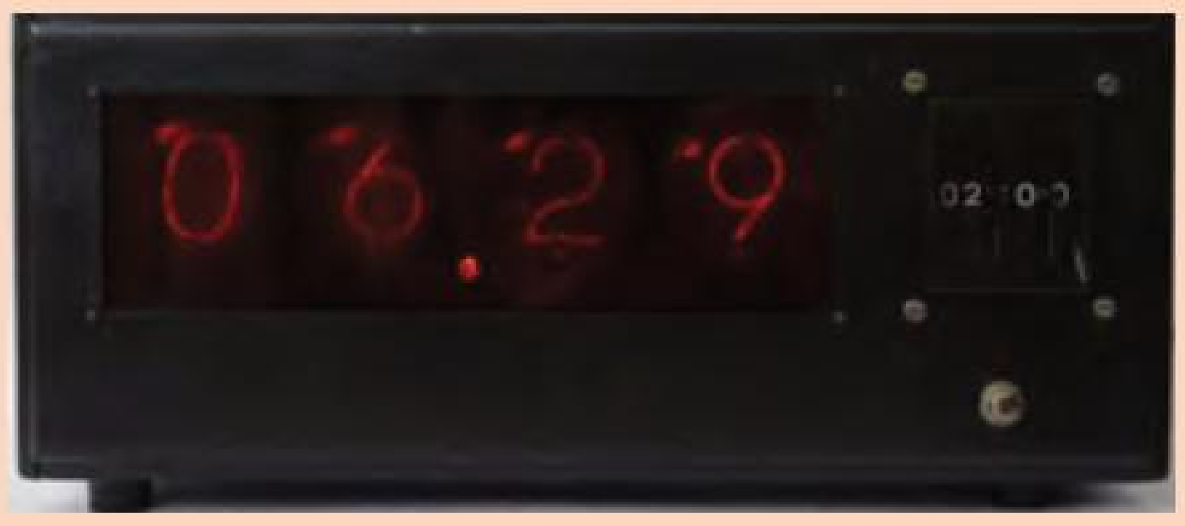
Exterior of the Digi-Clock *before refurbishment*



Internal view of the Digi-Clock



Internal view of the underside of the Digi-Clock



The exterior of the Digi-Clock *after refurbishment*

Legacy projects

Dear editor

I would greatly appreciate your help in obtaining a copy of the software for the *Earth Resistivity Meter* featured in *EPE* (Jan-Feb 1997) by Robert Beck, and the more recent *Earth Resistivity Logger* (Apr-May 2003) by John Becker.

Any assistance in obtaining the boards for these two projects would also be appreciated.

Last, do you have the email addresses of Robert Beck or John Becker?

Sidney Barnes

Alan Winstanley replies:
Thank you for contacting us. Software for legacy projects like these is still available at the following website address: ***www.epemag.net/microcontroller-code.htm***

The 1997 Earth Resistivity Meter *project had some QBASIC listings, which are in the PICs folder called 'Earth Meter' (even though I'm not sure it was a PIC program, I can't remember!). The 2003 version will be found in the folder called 'Earth Resistivity'.*

It would be necessary to fabricate the PCBs the old-fashioned way. We did not release PDF artwork online at that time. Our FAQ & Help page covering older issues is at: **www.epemag.com/library-help.html**

I'm afraid we don't release authors' email addresses but the design by Robert Beck is more than twenty years old and may not be viable to build today, and we are not in contact with him. I am sorry to say that our technical editor John Becker passed away some years ago.

Interest in these projects crops up from time to time and you can ask other EPE *readers for help by joining our simple forum at:* **www.chatzones.co.uk**

If you search for the keyword 'Resistivity' a number of legacy articles are available.

I am sorry we do not hold any more information, but I hope the above is of some help.

Air wiring

Dear editor
Your editorial in March 2017 referred to 'air wiring', or the 3D construction of electronic circuits without a PCB or baseboard. I first learned of this technique years ago from George Dobbs, G3RJV, of *Practical Wireless* and G-QRP Club fame. It relies on the strength of solder joints, unsupported except perhaps by the use of 1MΩ or 10MΩ resistors used as stand-off insulators. Their resistance is so high that they have no noticeable effect on the operation of the circuit.

The attached photos are of a small two-transistor RF oscillator I built for use with simple radio receivers, and which tunes around 5MHz. The stand-offs are soldered to the copper-clad board, which simply acts as an earth plane and a means of supporting the variable capacitor and switch. Output is taken from a disc capacitor leg left free.

Geoff Theasby, G8BMI

Dear editor
I read with interest *Max's Cool Beans* air wiring article and also Rev Thomas Scarborough's very clever *Heat Trick* (his circuits are ingenious) in March's *EPE*. It put me in mind of the *All Band Radio* published in September 2005 – another very clever design by Rev Scarborough.

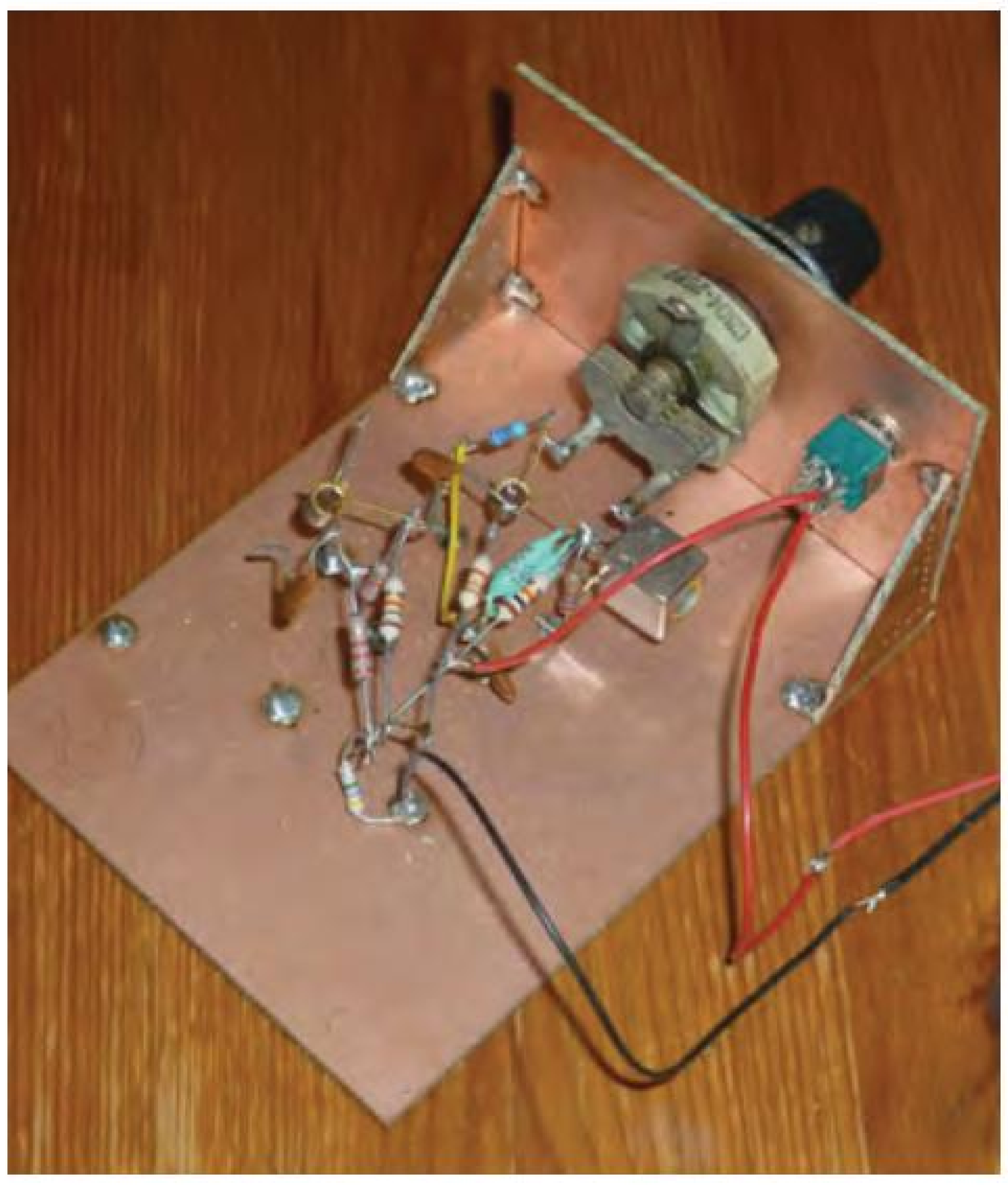
In 2006, I built the radio using air wiring – but in two dimensions, not three – as shown in the accompanying photos. My 13-year-old son is currently using it to good effect.

I have in mind to build the later version by Rev Scarborough (*EPE*, Oct 2010). The *AM Broadcast Band Portable Loop Antenna* (*EPE*, Jan 2011) is another project ear marked for construction, and I should also mention Raymond Haigh's articles – *Practical Radio Circuits: Part 4, Tuning*, which may be helpful with these little receivers (*EPE*, Sep 2003).

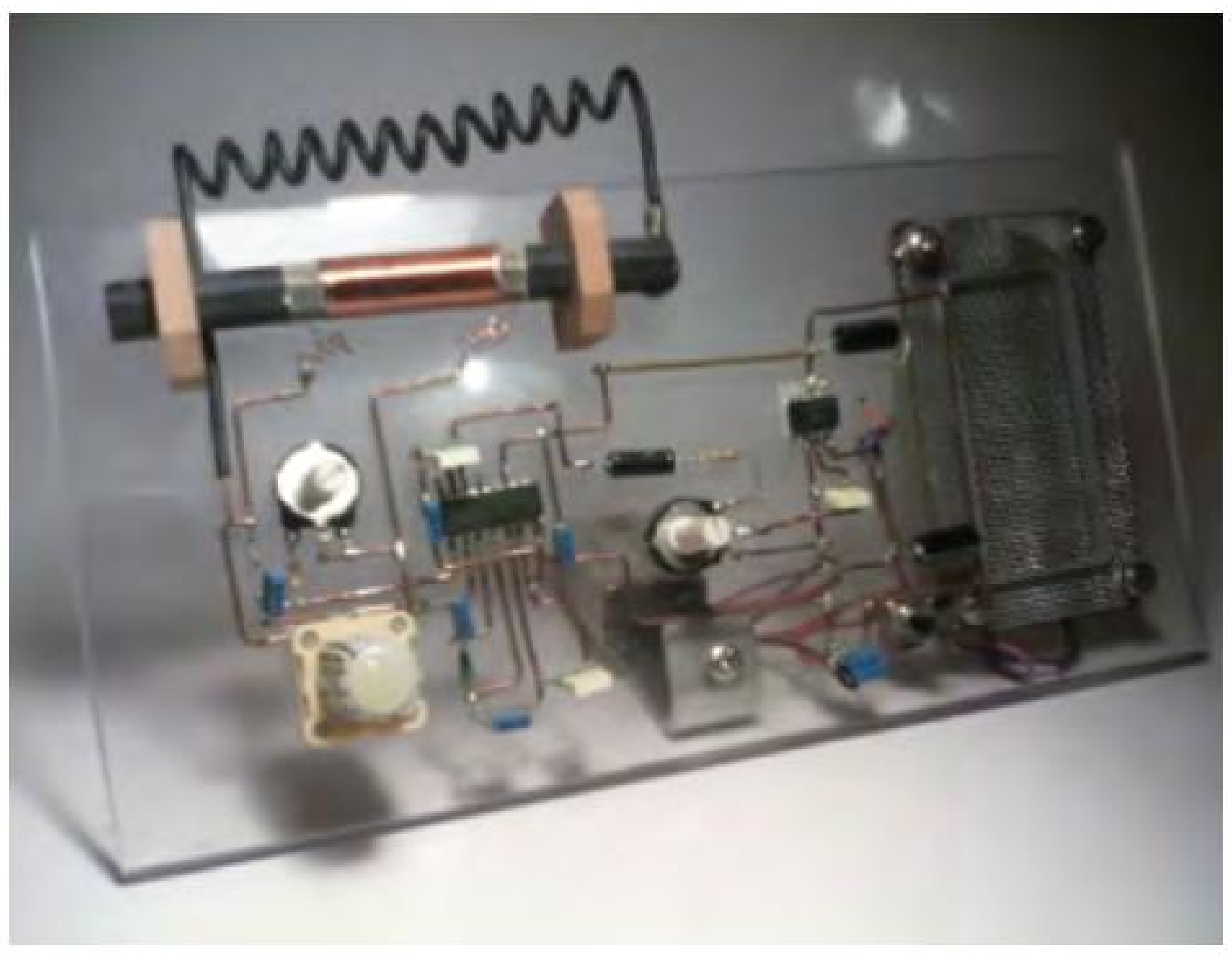
All this activity is a testament to *EPE* – always a brilliant publication!

Andrew Moore

Matt Pulzer replies:
Ncie work Geoff and Andrew – it's always good to see neat and inventive construction techniques. At times, it can be challenging to get consistently good soldering results when you have a handy substrate such as a well-made PCB or a piece of stripboard, but soldering in thin air really does take the art of soldering to a whole new level. Well done to both of you, and thank you for taking the time to share your circuits.



Air wiring of an RF oscillator by Geoff Theasby



Air wiring of a radio by Andrew Moore

Keep on trying!

Dear editor
Over the last year (or more) I've been trying to get to grips with making my own PCB's. Looking through past *EPE* magazines for tips and using trial and error techniques – I nearly gave up.

I asked for help on *Chat Zone* several times, but in the end, my lack of success led me to put aside my attempts – this is a costly hobby when failures occur!

About a fortnight ago, I got the whole lot out again, worked my way through *Chat Zone* advice and tried again. I'm pleased to say I succeeded – first, with a small board, then a larger one.

The first PCB, for test purposes, was a small 'tesla' circuit, based on an NE555, a MOSFET and handful of other components. I used PCB Wizard to create a schematic and the board design.

My chosen method is to use UV-resist boards and a four-tube exposure unit with an exposure time of 275 seconds (just over four and half minutes). Sodium meta-silicate is the developer. I use a heated etching tank made by Mega purchased on eBay for ten pounds – an absolute bargain.

I would like to say a big 'thank you' to everyone who helped me on *Chat Zone*. I received many suggestions and some good advice. *Chat Zone* is a great place for everyone who is either just tinkering with electronics or has been in the electronics industry all their lives.

Rich Cox

Matt Pulzer replies:
I'm delighted to hear your perseverance paid off. Your story rings true to me on two levels Like you, and probably most of us, there are times when a project 'just doesn't work'. It could be PCB construction, an uncooperative circuit or software that just sits there laughing at one's inability to spot an error. Often a bit of troubleshooting will clear a problem, but there are also times when it's best to say, 'this is a problem for another day' and simply put the project as side for a while. When you return, a fresh pair of eyes and an almost subconscious willingness to examine a problem from a different perspective can often work wonders.

Second, it's good to hear you found support and help in Chat Zone. *It really is a gold mine of experience and helpful tips. There's not much new under the sun – and if you have a project problem, then chances are good that someone else has been there, got the tee shirt and will be able to give you the benefit of their hard-earned experience.*

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS IN READOUT PLEASE EMAIL US AT:

editorial@wimborne.co.uk

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

From £49.00

TINA Design Suite V10

FEATURED IN OUR TEACH-IN 2015 SERIES

Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation and PCB Design with TINA

TINA Design Suite V10 is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter and analyse any circuit up to 100 nodes (student), or 200 with the Basic (Hobbyist) version within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments.

Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create and print documents directly inside TINA or cut and paste your results into your favourite word procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

This offer gives you a CD-ROM – the software will need registering (FREE) with Designsoft (TINA), details are given within the package.

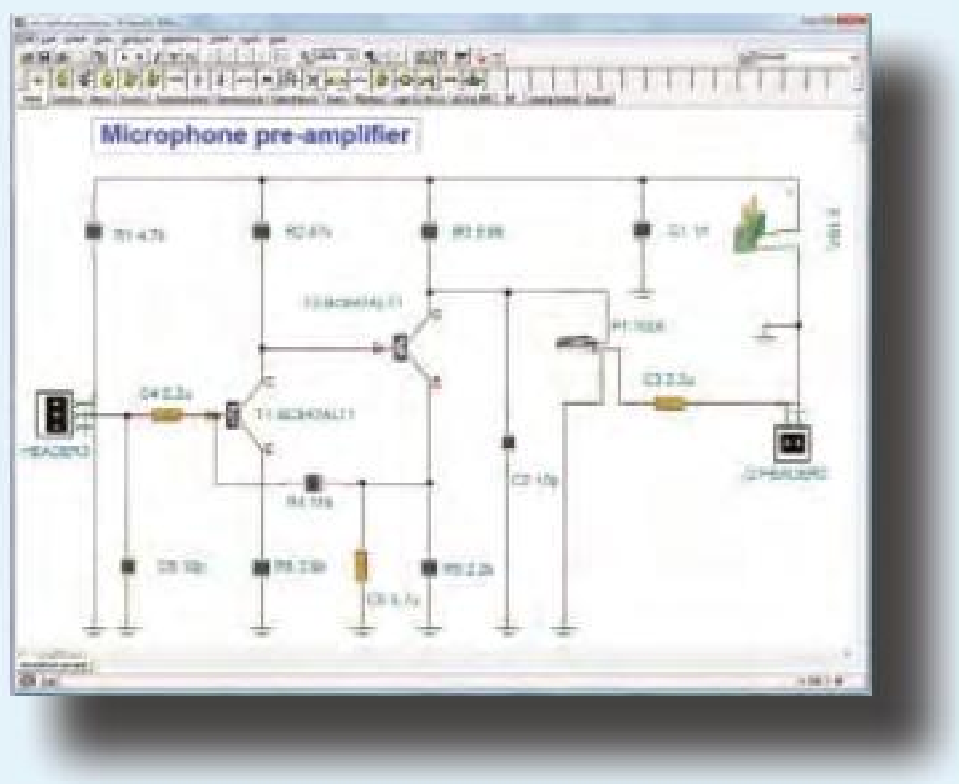
Get TINA Basic V10 (Hobbyist) for £129 or Student V10 version for £49

Prices include VAT and UK postage

+ get a 1 year free subscription for TINACloud the breakthrough cloud version of TINA which you can run on most operating systems and computers, including PCs, Macs, thin clients iPads and other tablets – even on many smart phones, smart TVs and e-book readers.

To order please either fill out and return the order form, or call us on 01202 880299

Alternatively you can order via our secure online shop at: www.epemag.com



ELECTRONICS TEACH-IN 2

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

ELECTRONICS TEACH-IN 3

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

CD-ROM **Order code ETI3 CD-ROM** **£8.50**

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM

A Broad-Based Introduction to Electronics.
The Teach-In 4 CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The CD-ROM also contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

CD-ROM **Order code ETI4 CD-ROM** **£8.99**

ELECTRONICS TEACH-IN 4
A BROAD-BASED INTRODUCTION TO ELECTRONICS
THE MODERN ELECTRONICS MANUAL
ELECTRONICS TEACH-IN 3
CIRCUIT SURGERY
PRACTICALLY SPEAKING
INGENUITY UNLIMITED

NEW ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2, 3 & 4

CD-ROMs **Order code ETIB2** Bundle Price **£18.95**

PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories

£118 including VAT and postage

SOFTWARE

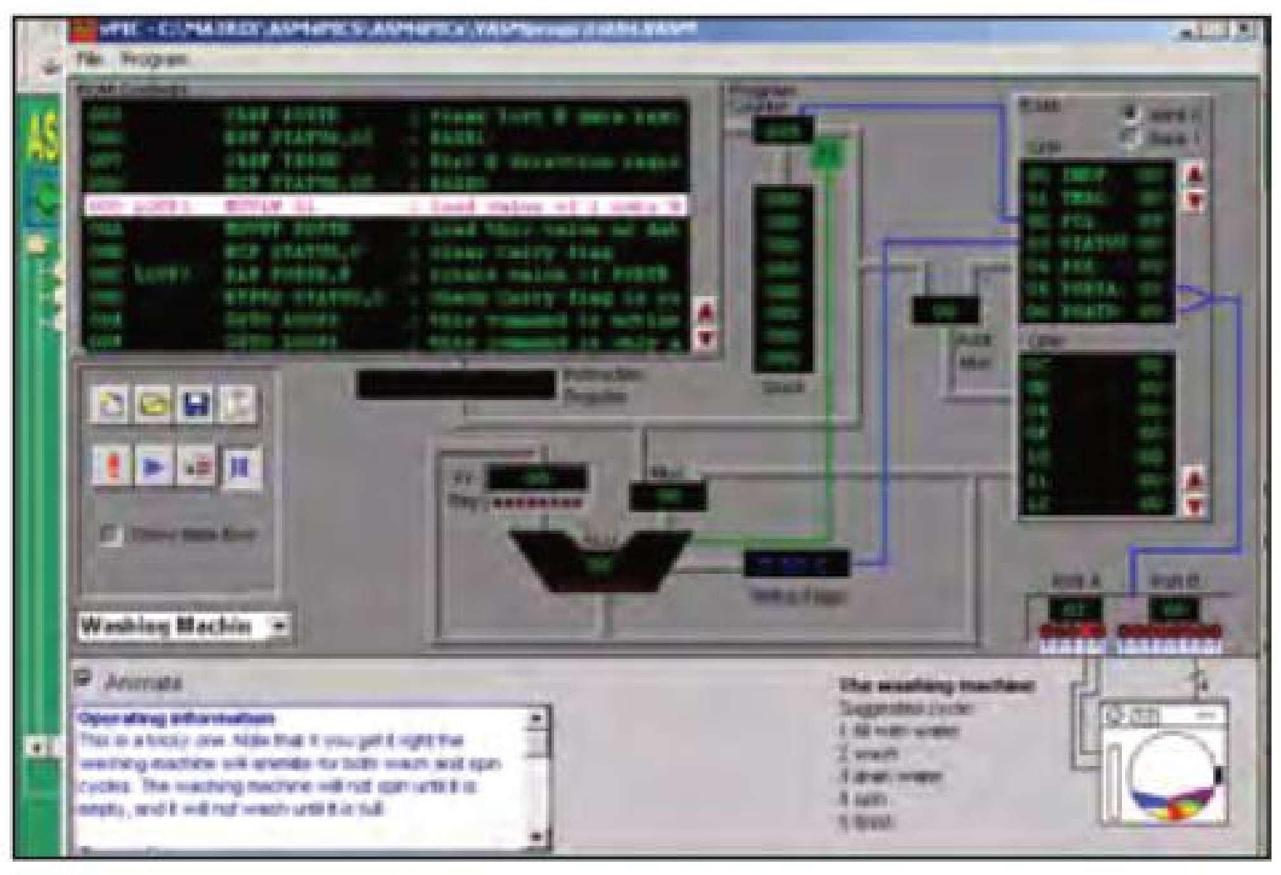
ASSEMBLY FOR PICmicro V6

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84, 16F88 and 16F877a PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

• Comprehensive instruction through 45 tutorial sections • Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator • Tests, exercises and projects covering a wide range of PICmicro MCU applications • Includes MPLAB assembler • Visual representation of a PICmicro showing architecture and functions • Expert system for code entry helps first time users • Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) • Imports MPASM files.

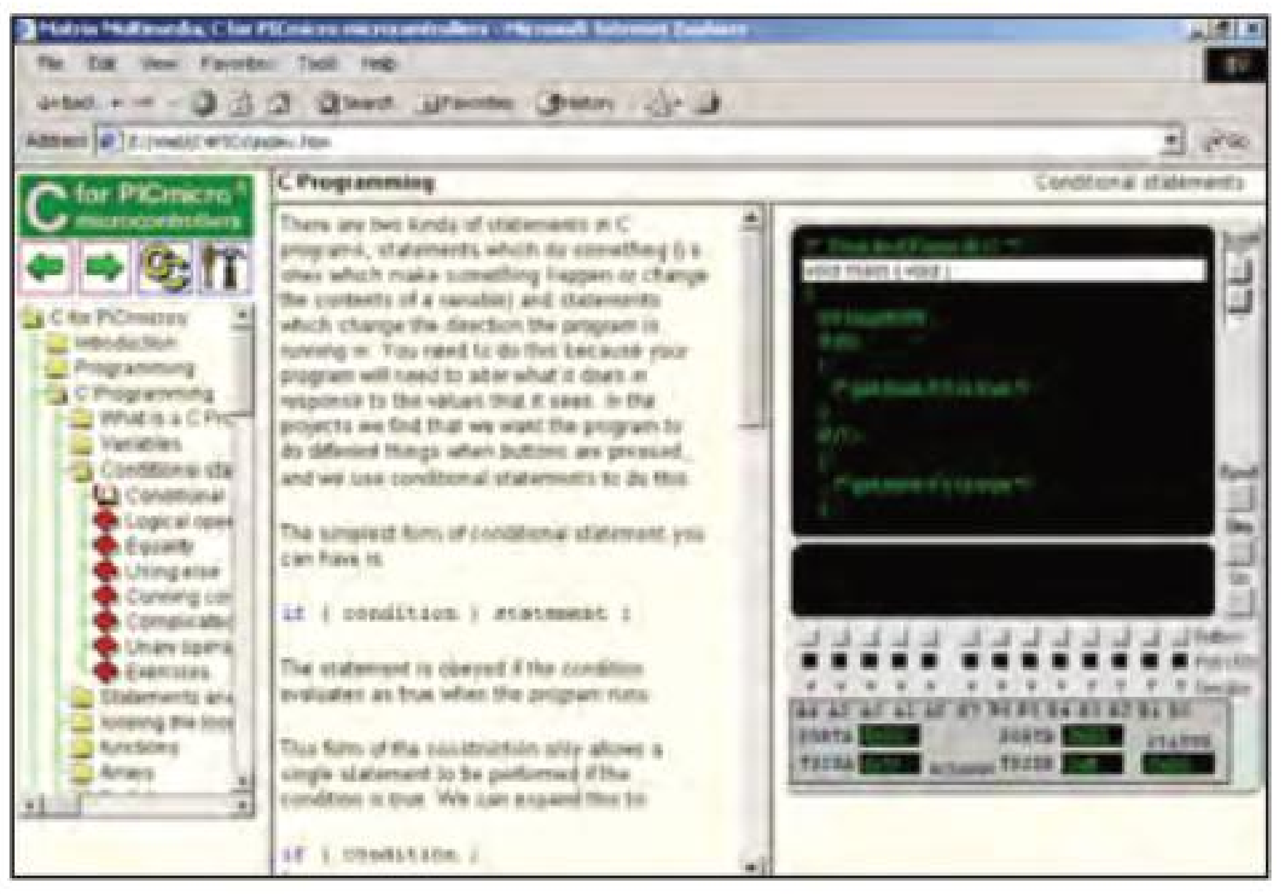


'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

• Complete course in C as well as C programming for PICmicro microcontrollers • Highly interactive course • Virtual C PICmicro improves understanding • Includes a C compiler for a wide range of PICmicro devices • Includes full Integrated Development Environment • Includes MPLAB software • Compatible with most PICmicro programmers • Includes a compiler for all the PICmicro devices.



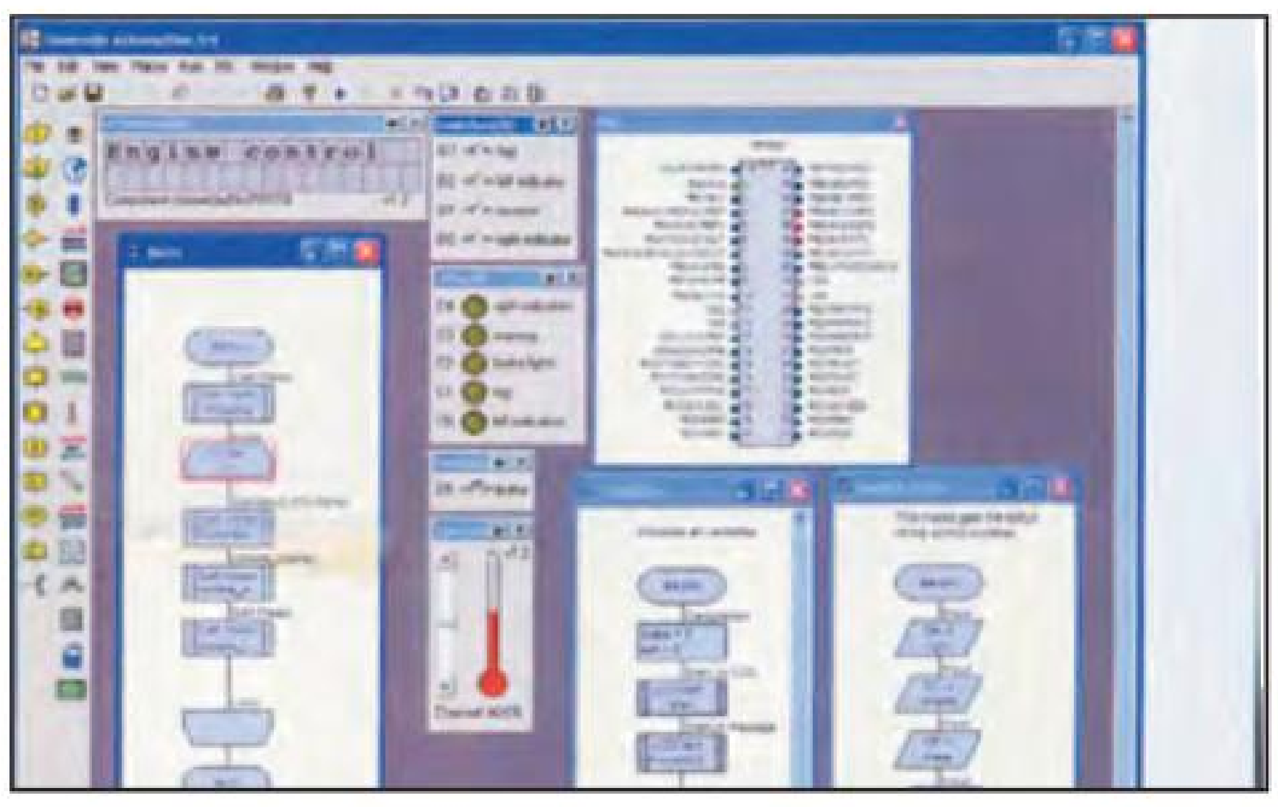
This software will run on Windows XP or later operating systems

FLOWCODE FOR PICmicro V7

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces code for a wide range of devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Please note: Due to popular demand, Flowcode is now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you.



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Single License . . . . £99 plus VAT

Site Licence . . . . £499 plus VAT

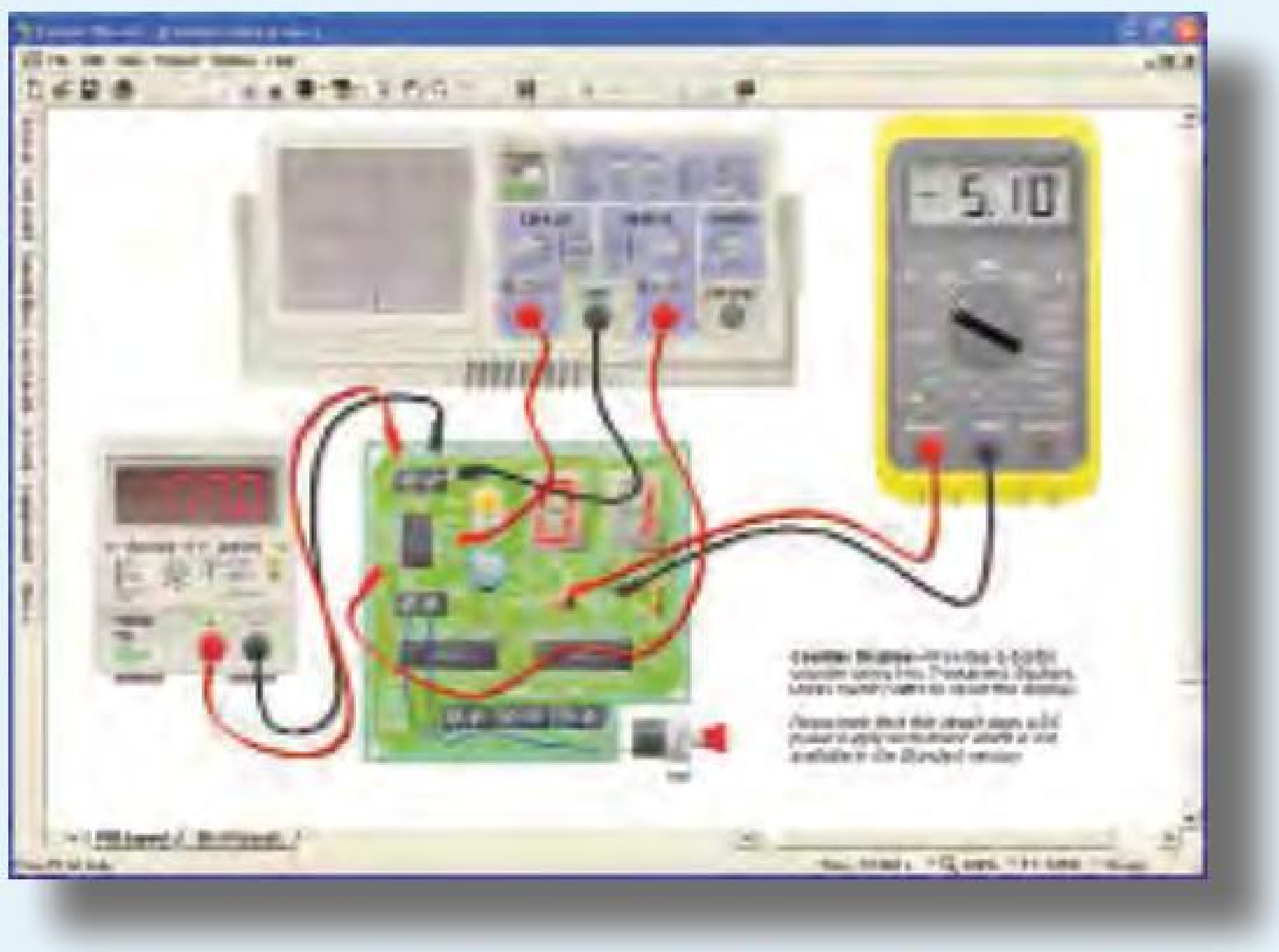
Flowcode . . . . Contact us for pricing
(choose PIC-8b, PIC-16b, PIC-32b, AVR/Arduino,ARM)

CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package. Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

** Circuit diagram design with component library (500 components Standard, 1500 components Professional) * Virtual instruments (4 Standard, 7 professional) * On-screen animation * Interactive circuit diagram simulation * True analogue/digital simulation * Simulation of component destruction * PCB Layout * Interactive PCB layout simulation * Automatic PCB routing * Gerber export * Multi-level zoom (25% to 1000%) * Multiple undo and redo * Copy and paste to other software * Multiple document support*



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT. Professional **£75** plus VAT.

GCSE ELECTRONICS

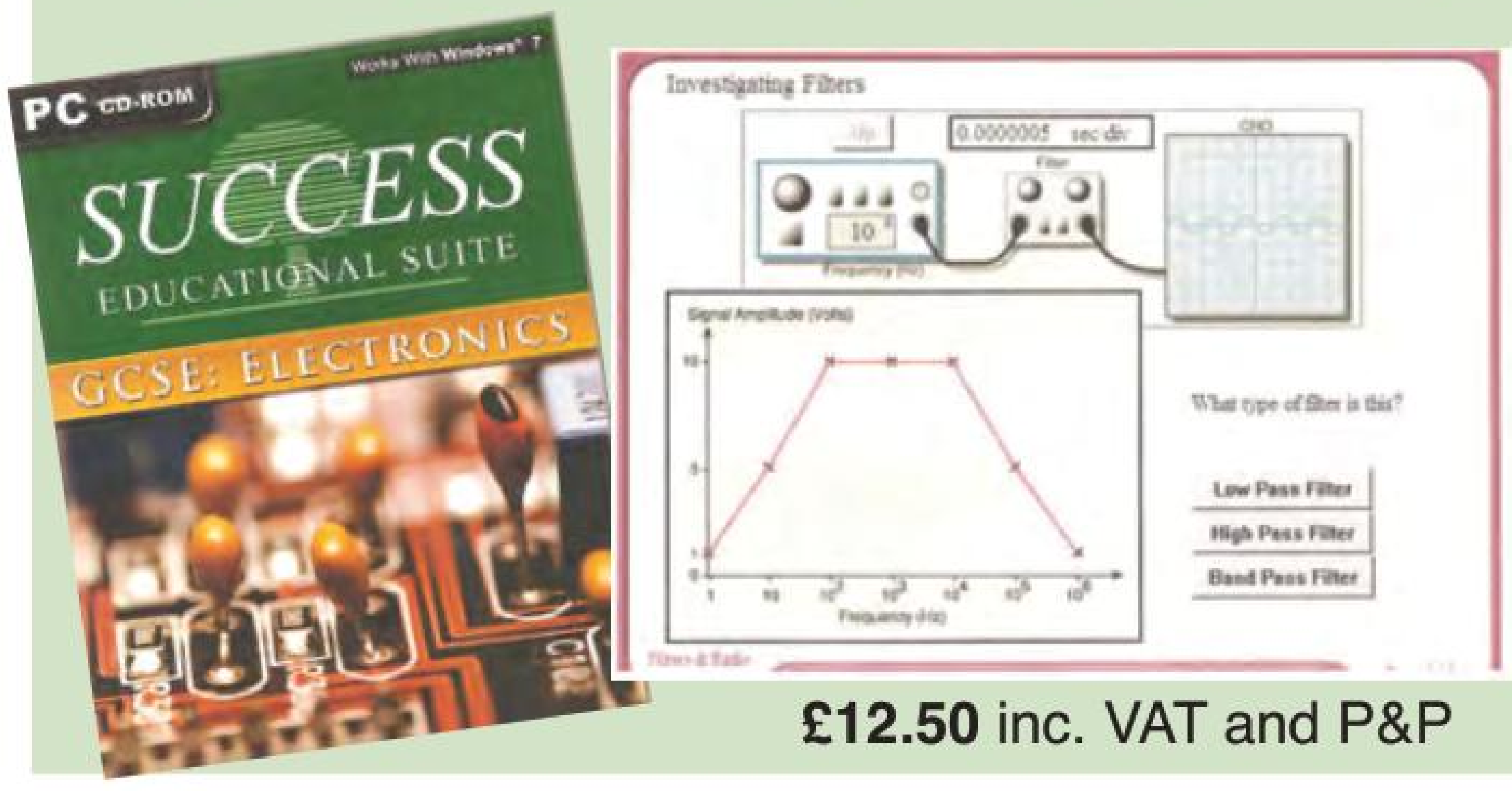
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

**** Contains comprehensive teaching material to cover the National Curriculum syllabus * Regular exercises reinforce the teaching points * Retains student interest with high quality animation and graphics * Stimulates learning through interactive exercises * Provides sample examination ques-tions with model solutions * Authored by practising teachers * Covers all UK examination board syllabuses * Caters for all levels of ability * Useful for self-tuition and revision***

SUBJECTS COVERED

Electric Circuits – Logic Gates – Capacitors & Inductors – Relays – Transistors – Electric Transducers – Operational Amplifiers – Radio Circuits – Test Instruments

Over 100 different sections under the above headings



£12.50 inc. VAT and P&P

Please send me: **CD-ROM ORDER FORM**

☐ **Assembly for PICmicro V5**
☐ **'C' for 16 Series PICmicro V5**

Version required:
☐ **Single License**
☐ **Site licence**

Note: The software on each version is the same, only the licence for use varies.

☐ **PICmicro Multiprogrammer Board and Development Board (hardware)**

☐ **Circuit Wizard – Standard**
☐ **Circuit Wizard – Professional**
☐ **GCSE Electronics**

☐ **TINA Design Suite V10 Basic (Hobbyist)**
☐ **TINA Design Suite V10 (Student)**

☐ **Teach-In 2**
☐ **Teach-In 3**
☐ **Teach-In 4**
☐ **Teach-In Bundle**

Full name: . . . .

Address: . . . .

. . . . Post code: . . . . Tel. No: . . . .

Signature: . . . .

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ . . . .
☐ Please charge my Visa/Mastercard: £ . . . .

Valid From: . . . . Card expiry date: . . . .

Card No: . . . .

Card Security Code . . . .

(The last 3 digits on or just under the signature strip)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

ORDERING

ALL PRICES INCLUDE UK POSTAGE

Standard/Student/Basic (Hobbyist) Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Single License and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU

To order by phone ring

01202 880299. Fax: 01202 843233
Goods are normally sent within seven days

E-mail: orders@wimborne.co.uk

Online shop:

www.epemag.com

GET THE LATEST COPY OF OUR TEACH-IN SERIES

AVAILABLE 28th April

ON SALE in WHSmith and other independent newsagents FROM 28th APRIL 2017

FREE CD-ROM
£8.99
ELECTRONICS TEACH-IN 8
FREE CD-ROM SOFTWARE FOR THE TEACH-IN 8 SERIES
FROM THE PUBLISHERS OF EPE EVERYDAY PRACTICAL ELECTRONICS
INTRODUCING THE ARDUINO
• Hardware – learn about components and circuits
• Programming – powerful integrated development system
• Microcontrollers – understand control operations
• Communications – connect to PCs and other Arduinos
EPE EVERYDAY PRACTICAL ELECTRONICS TEACH-IN 8
SOFTWARE FOR THE TEACH-IN 8 SERIES
PLUS...
PIC n'MIX
PICs and the PICkit 3 - A beginners guide. The why and how to build PIC-based projects
ISBN 978-1-896805-30-4

Teach-In 8 – Exploring the Arduino

This exciting series has been designed for electronics enthusiasts who want to get to grips with the inexpensive, immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. Teach-In 8 provides a one-stop source of ideas and practical information.

The Arduino offers a remarkably effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle through wireless or the Internet. Teach-In 8 is based around a series of practical projects with plenty of information to customise each project. The projects can be combined together in many different ways in order to build more complex systems that can be used to solve a wide variety of home automation and environmental monitoring problems. To this end the series includes topics such as RF technology, wireless networking and remote Web access.

PLUS: PICs and the PICkit 3 - A beginners guide

The why and how to build PIC-based projects. An extra 12 part series based around the popular PIC microcontroller.

FREE COVER-MOUNTED CD-ROM

Containing the software for the two series

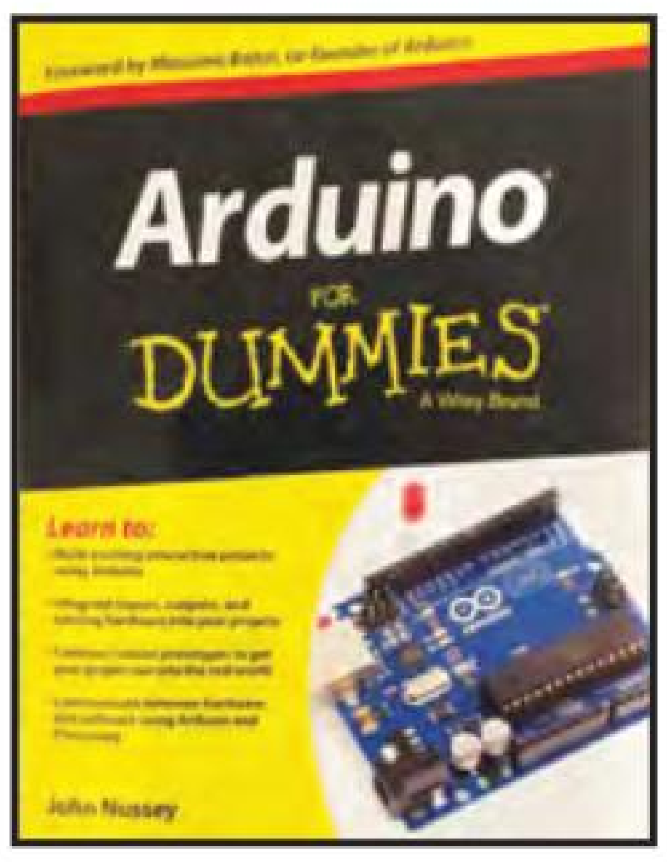
PRICE £8.99

(includes P&P if ordered direct from us)

PRE-ORDER YOUR COPY TODAY JUST CALL 01202 880299

DIRECT BOOK SERVICE

Teach-In 2016
Exploring the Arduino

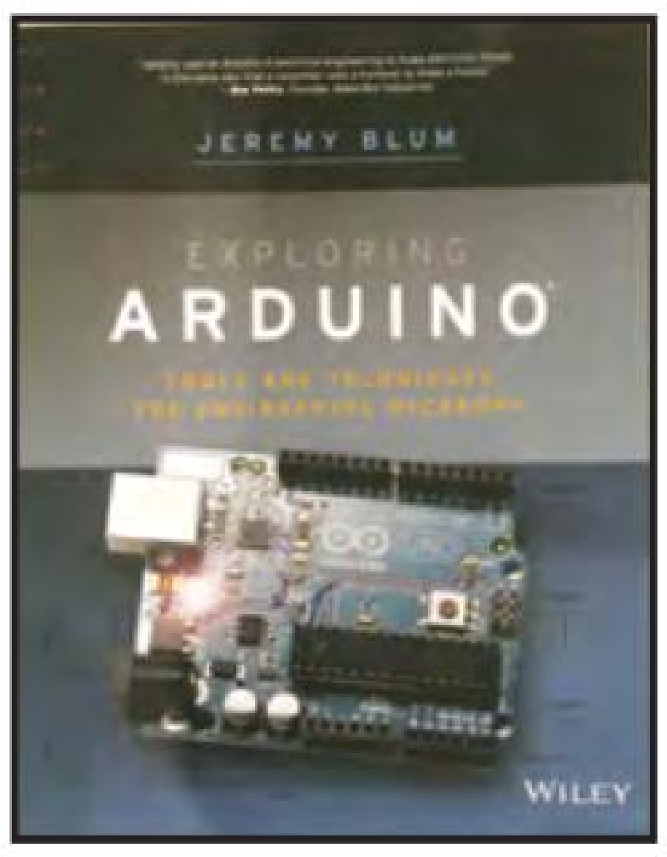


ARDUINO FOR DUMMIES
John Nussey

Arduino is no ordinary circuit board. Whether you're an artist, a designer, a programmer, or a hobbyist, Arduino lets you learn about and play with electronics. You'll discover how to build a variety of circuits that can sense or control real-world objects, prototype your own product, and even create interactive artwork. This handy guide is exactly what you need to build your own Arduino project – what you make is up to you!

- Learn by doing – start building circuits and programming your Arduino with a few easy examples – right away!
- Easy does it – work through Arduino sketches line by line, and learn how they work and how to write your own.
- Solder on! – don't know a soldering iron from a curling iron? No problem! You'll learn the basics and be prototyping in no time.
- Kitted out – discover new and interesting hardware to turn your Arduino into anything from a mobile phone to a Geiger counter.
- Become an Arduino savant – find out about functions, arrays, libraries, shields and other tools that let you take your Arduino project to the next level
- Get social – teach your Arduino to communicate with software running on a computer to link the physical world with the virtual world

438 Pages Order code ARDDUM01 £19.99



EXPLORING ARDUINO
Jeremy Blum

Arduino can take you anywhere. This book is the roadmap.

Exploring Arduino shows how to use the world's most popular microcontroller to create cool, practical, artistic and educational projects. Through lessons in electrical engineering, programming and human-computer interaction this book walks you through specific, increasingly complex projects, all the while providing best practices that you can apply to your own projects once you've mastered these. You'll acquire valuable skills – and have a whole lot of fun.

• Explore the features of several commonly used Arduino boards • Use the Arduino to control very simple tasks or complex electronics • Learn principles of system design, programming and electrical engineering • Discover code snippet, best practices and system schematics you can apply to your original projects • Master skills you can use for engineering endeavours in other fields and with different platforms

357 Pages Order code EXPARD01 £26.99

THEORY AND REFERENCE

PRACTICAL ELECTRONICS HANDBOOK – 6th Edition. Ian Sinclair
440 pages Order code NE21 £33.99

Starting
Electronics

STARTING ELECTRONICS – 4th Edition
Keith Brindley
296 pages Order code NE100 £18.99

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS – Third Edition Mike Tooley
400 pages Order code TF43 £25.99

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES – Third Edition C.R. Robertson
368 pages Order code TF47 £21.99

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R.A. Penfold
142 pages OUT OF PRINT BP332 £5.45

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop
228 pages Order code NE35 £36.99

PROJECT CONSTRUCTION

IC 555 PROJECTS
E. A. Parr
167 pages Order code BP44 £5.49

ELECTRONIC PROJECT BUILDING FOR BEGINNERS R. A. Penfold
135 pages Order code BP392 £5.99

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
132 pages Order code BP374 £5.45

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last page.

FOR A FULL DESCRIPTION OF THESE BOOKS AND CD-ROMS SEE THE SHOP ON OUR WEBSITE
www.epemag.com

All prices include UK postage

MICROPROCESSORS

INTERFACING PIC MICROCONTROLLERS – SECOND EDITION Martin Bates
298 pages Order code NE48 £34.99

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)
496 pages +CD-ROM Order code NE45 £38.00

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp
222 pages Order code NE31 £29.99

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION. John Morton
270 pages Order code NE36 £25.00

PIC IN PRACTICE (2nd Edition)
David W. Smith
308 pages Order code NE39 £24.99

MICROCONTROLLER COOKBOOK
Mike James
240 pages Order code NE26 £36.99

BOOK ORDERING DETAILS

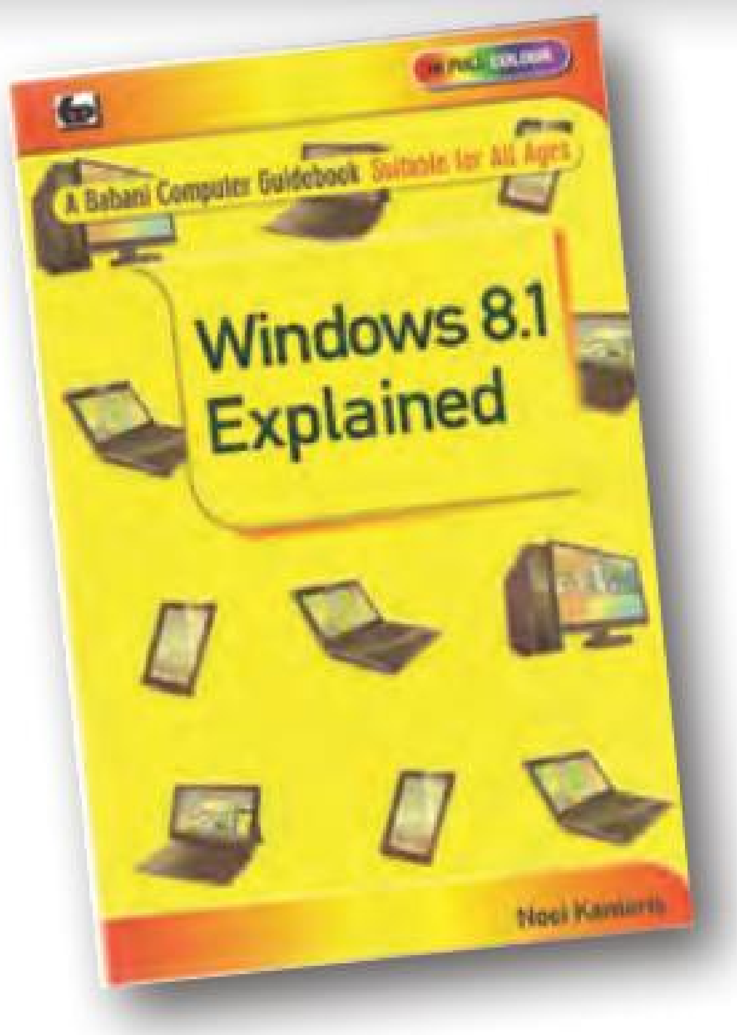
All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. Surface mail can take up to 10 weeks to some countries. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU**.

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a full description of these books please see the shop on our website.
Tel 01202 880299 Fax 01202 843233. E-mail: dbs@wimborne.co.uk

Order from our online shop at: www.epemag.com

FULL COLOUR COMPUTING BOOKS



WINDOWS 8.1 EXPLAINED

Windows 8.1 is the latest version of Microsoft's operating system. It is installed on all new Windows Desktop. Laptop and X86 tablet computers and is also available as a free upgrade. Whether you choose to use the touch screen Tile interface or the mouse operated Desktop interface, a good working knowledge of the operating system is essential to get the most from your computer and this book will help you to do just that.

The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

Among the many topic covered are: An overview of the Tile Interface, Desktop, Taskbar, Tray Notification Area, Charms bar and running Apps; managing Windows settings, personalising your PC and creating User Accounts; using the Desktop File Explorer, SkyDive, Internet Explorer and the E-mail App; working with and organising digital photographs, using Media Player to play and store music and to burn CDs and installing Media Center to play DVDs; connecting to wireless networks, setting up a HomeGroup, sharing a printer and networked PCs; using mobility tools to keep your laptop running while away from home; accessibility features should you have dexterity or eyesight problems; keeping your computer healthy and backing up important files; And much more besides…..

180 Pages **Order code BP747** **£10.99**

HOW TO FIX YOUR PC PROBLEMS
R.A. Penfold

128 pages **Order code BP705** **£8.49**

AN INTRODUCTION TO WINDOWS VISTA
P.R.M. Oliver and N. Kantarris

120 pages **Order code BP703** **£8.49**

A Babani Computer Guidebook Suitable for All Ages
Kindle Fire HDX Explained
Noel Kantaris

KINDLE FIRE HDX EXPLAINED

This book is written to help users get to grips, quickly and easily, with the amazing Kindle Fire HDX tablet. You will be guided through the configuration and use of the Kindle Fire HDXs facilities and functions. This book was written using the 7" HDX but it is also applicable to the 8.9" model.

Among the many topics covered are: An overview of the Kindle Fire HDX. Charging and setting up, connecting to a Wi-Fi network, registering the device and connecting to Social Networks; setting up and using the 1-Click Amazon account for buying and downloading books, music and other content that you have searched for. Explaining the use of the Carousel. Starting screen Apps. Web and Device settings and the Mayday facility; browsing the web with Silk Internet explorer, using Bookmarks and History, printing web pages, documents and messages; connecting to a server to send and receive e-mail messages, using and saving attachments. Creating and organising your Contacts and Calendar appointements; using the Kindle Fire camera to take photos and videos. Watching TV, listening to music you bought, imported and from the radio. Using the X-ray feature with books and other media; Using the OfficeSuite to view your documents, upgrading to OfficeSuite Professional 7 to allow both viewing and creation of Word documents. Excel spreadsheets and PowerPoint presentations. And more besides...

This book will help you acquire the skills needed to understand and make the most of your Kindle Fire HDX.

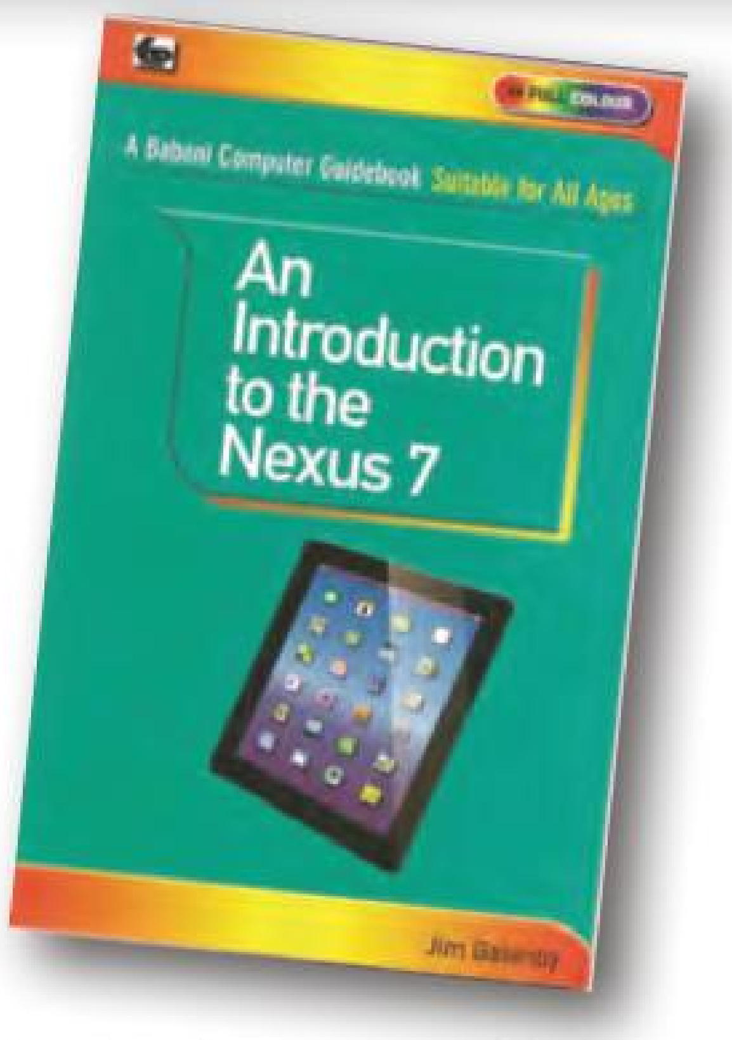
118 Pages **Order code BP743** **£8.99**

COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION
R.A. Penfold

120 pages **Order code BP702** **£8.49**

AN INTRODUCTION TO EXCEL SPREADSHEETS
Jim Gatenby

18 pages **Order code BP701** **£8.49**


A Babani Computer Guidebook Suitable for All Ages
An Introduction to the Nexus 7
Jim Gatenby

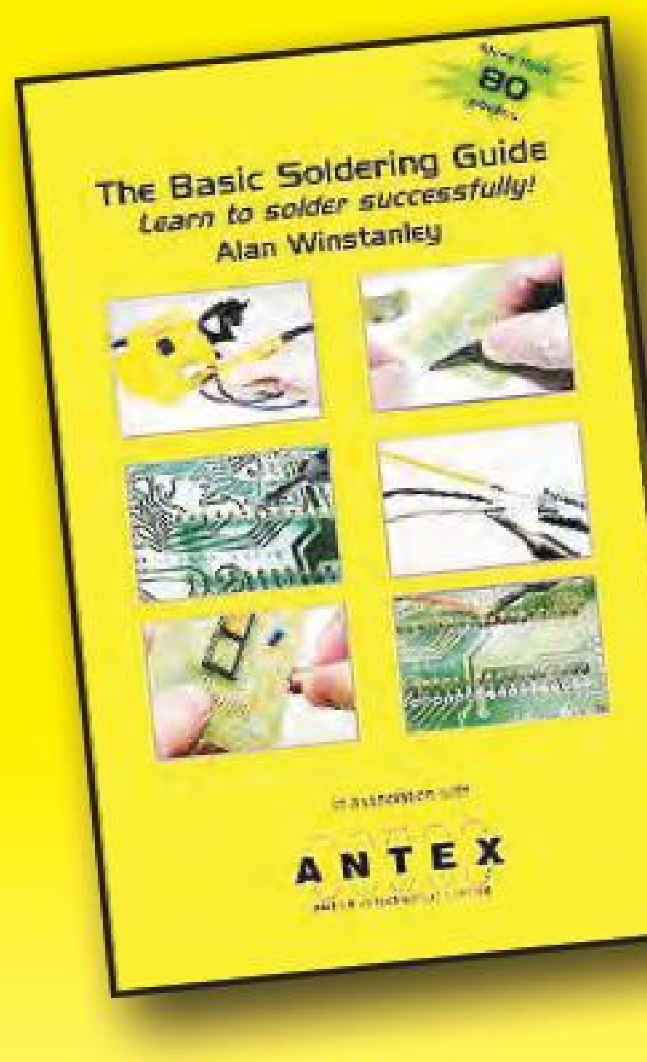
AN INTRODUCTION TO THE NEXUS 7

This book is intended for the new user of the Nexus 7, although much of it will also apply to the Nexus 10. It is easy to understand being written in plain English and avoiding technical jargon wherever possible.

Among the many useful topics covered are: An overview of the main features of the Nexus 7; setting up the Nexus 7; charging the battery; connecting to the Internet and signing up for Gmail; touch-screen operation and navigating around the various screens; installing Apps from the Google Play Store; setting a password and other precautions to keep your files safe; connecting accessories such as a USB Drive, mouse and keyboard; enjoying entertainment such as eBooks, games, music and videos; searching the Internet, including speaking in keywords; using e-mail, Skype and social networking; installing the free Google Drive app to save your documents in the cloud; using Google Docs free word processing and spreadsheet software; printing a document using Google Cloud Print, Exporting Nexus 7 files to laptop and desktop computers; and much more besides….

Even if you are a complete beginner, this book will help you to easily acquire the skills needed to understand and make the most of the Nexus 7.

118 Pages **Order code BP744** **£8.99**



THE BASIC SOLDERING GUIDE HANDBOOK

LEARN TO SOLDER SUCCESSFULLY!
ALAN WINSTANLEY

The No.1 resource to learn all the basic aspects of electronics soldering by hand.

With more than 80 high quality colour photographs, this book explains the correct choice of soldering irons, solder, fluxes and tools. The techniques of how to solder and desolder electronic components are then explained in a clear, friendly and non-technical fashion so you'll be soldering successfully in next to no time! The book also includes sections on Reflow Soldering and Desoldering Techniques, Potential Hazards and Useful Resources. Plus a Troubleshooting Guide.

Also ideal for those approaching electronics from other industries, the Basic Soldering Guide Handbook is the best resource of its type, and thanks to its excellent colour photography and crystal clear text, the art of soldering can now be learned by everyone!

86 Pages **Order code AW1** **£9.99**

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date.......................................

Card Number .... Maestro Issue No.............................

Valid From Date .... Card Security Code .... (The last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

Max's Cool Beans

By Max The Magnificent

The secret of my success

I've recently run across an active stylus plus handwriting app combo for my iPad Pro that has completely changed the way I work and is dramatically boosting my productivity. I'll be delighted to share the secrets of the ancients with you, but first let me set the scene...

No peace for the wicked

I don't know about you, but I'm almost invariably to be found working on something or other. During the weekdays, I have my full-time job, of course. At the weekends, I typically have one or more hobby projects on the go. And in the evenings, while ensconced in my comfy chair, sitting in the family room with my wife (Gina the Gorgeous) and my son Joseph, I'm usually either reading a book, writing a book, or penning an article (like this one, for example).

Something to be desired

I've tried working on my laptop computer, but that has not proved to be particularly effective for a variety of reasons, including having to run a power cord around the room when its battery gets low. Also, in addition to the words – which are, needless to say, hand-plucked on the north side of the hill at the crack of dawn while still glistening with dew and at the peak of freshness – I need to capture sketches and circuit diagrams and suchlike. When I'm working in my office, I use Microsoft Visio for this sort of thing, but that requires the use of a mouse, which is awkward when one is installed in a comfy chair.

The tragedy of the iPad

The late, great Isaac Asimov wrote a very interesting book called, *The Tragedy of the Moon*. His premise was that the moon's tragedy was that it orbited the Earth, which helped confirm people's natural assumptions that the Earth was flat; that the sun, moon, and stars moved around the Earth; that the Earth was therefore the center of the universe; and that humans were therefore the most important things in the universe. I'll explain where I'm going with this in a moment, but first…

When I first acquired my iPad Pro, I had delightful daydreams of using it to capture my handwritten notes and sketches. This idea was especially attractive in the case of airplanes, because I usually end up in lower-economy class crammed into a joke of a seat with my knees wrapped around my ears.

Sadly, my hopes were cruelly dashed. When I was young and (even more) foolish, my mother begged me to learn how to type, but this was before the widespread use of computers and I couldn't see the point, so it's ironic that I now spend all my working days slaving over a hot keyboard. The result is that I'm the fastest two-fingered hunt-and-peck typist in the west, but that's on a real, hard (physical) keyboard. For some reason I can't explain, I type like a drongo on the iPad's soft (virtual) keyboard.

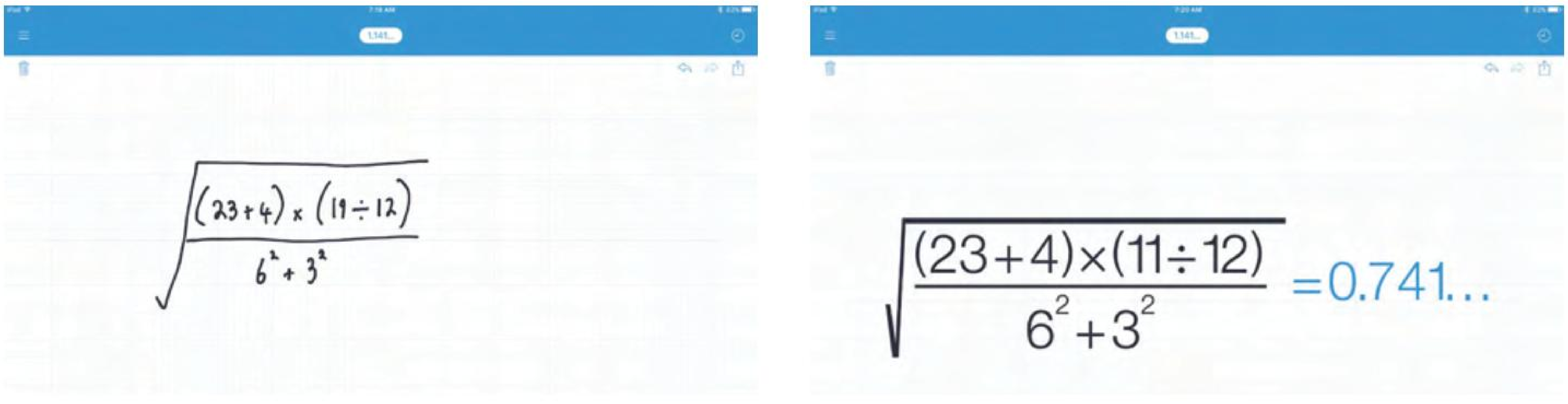
I've also tried a variety of handwriting apps coupled with traditional passive styluses, but the result has not been pleasant. In the case of the apps themselves, they are either too simplistic for my needs or so complicated to learn that my brains leak out of my ears. With regard to using a passive stylus, the result typically ends up looking like I only just learned to write earlier in the day.

Living with disappointment

I was just thinking of Alexander Pope (1688-1744) who once said: 'Blessed is he who expects nothing, for he shall never be disappointed.' In turn, this reminded me of the movie, *The Rocky Horror Picture Show* – the part where Magenta says, 'I ask for nothing master,' to which Frank-N-Furter replies, 'And you shall receive it. IN ABUNDANCE!' But I digress…

Until a week or so ago, the best option I'd got was to use paper and pencil. The big advantage here is the ability to quickly and easily capture both words and diagrams. One slight problem is the way I work, which involves constantly bouncing back and forth, adding things, deleting things, and modifying things. The end result is lots of text being scratched out, little notes all over the place, and arrows pointing forward and backward with puzzling annotations like, 'Move this bit to after the part about the pickled cabbage.'

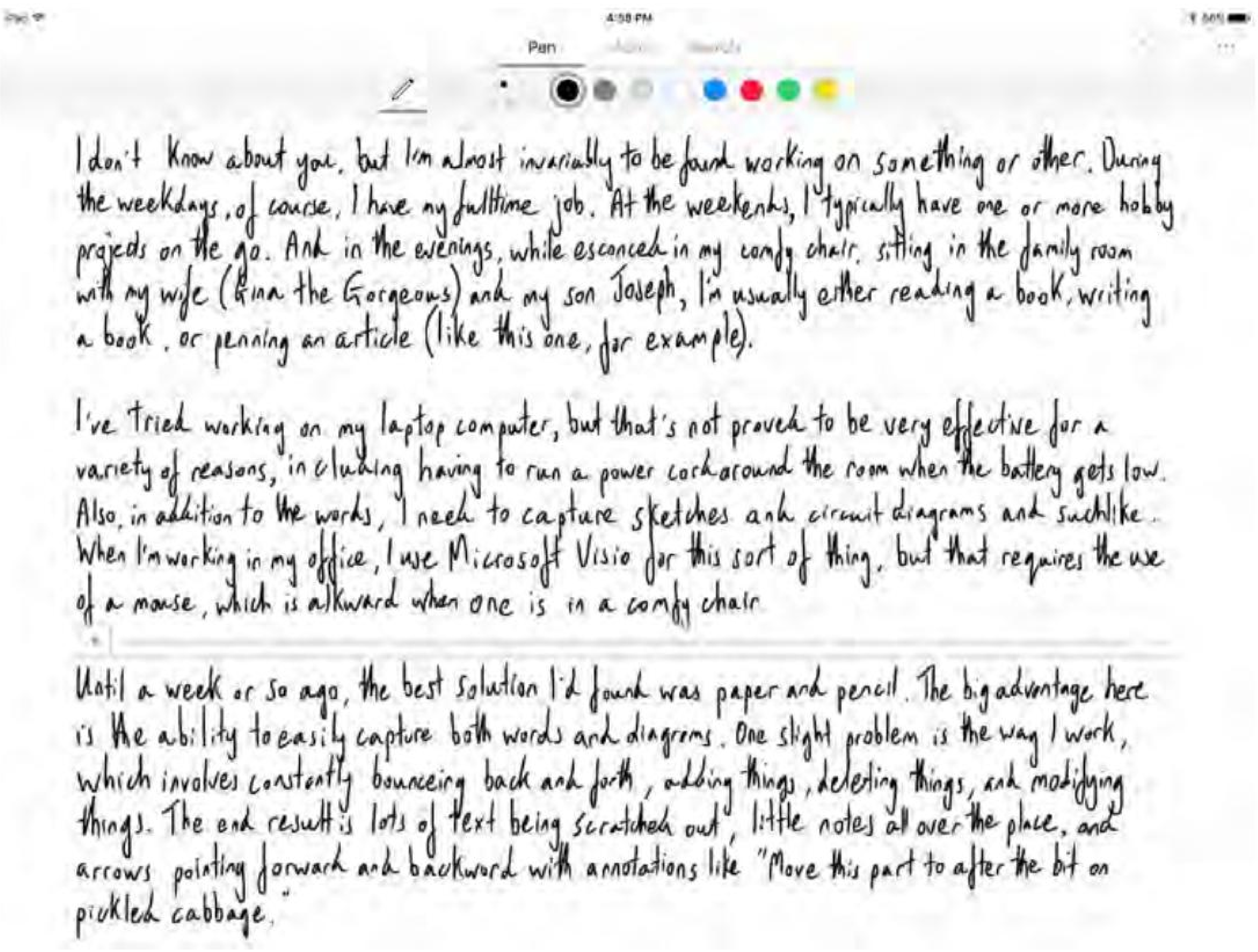
The biggest disadvantage of the pencil and paper regime is the fact that I have to transcribe the text and recreate the diagrams later, which can be something of a pain, not least that even I find it difficult to decipher



$$\sqrt{\frac{(23+4)\times(11\div12)}{6^2+3^2}}$$

$$\sqrt{\frac{(23+4)\times(11\div12)}{6^2+3^2}} = 0.741\ldots$$

Fig.1. Using the MyScript Calculator: (left) Enter the calculation by hand, (right) The calculator determines the result



I don't Know about you, but I'm almost invariably to be found working on something or other. During the weekdays, of course, I have my fulltime job. At the weekends, I typically have one or more hobby projects on the go. And in the evenings, while esconced in my comfy chair, sitting in the family room with my wife (Gina the Gorgeous) and my son Joseph, I'm usually either reading a book, writing a book, or penning an article (like this one, for example).

I've tried working on my laptop computer, but that's not proved to be very effective for a variety of reasons, including having to run a power cord around the room when the battery gets low. Also, in addition to the words, I need to capture sketches and circuit diagrams and suchlike. When I'm working in my office, I use Microsoft Visio for this sort of thing, but that requires the use of a mouse, which is awkward when one is in a comfy chair

Until a week or so ago, the best solution I'd found was paper and pencil. The big advantage here is the ability to easily capture both words and diagrams. One slight problem is the way I work, which involves constantly bounceing back and forth, adding things, deleting things, and modifying things. The end result is lots of text being scratched out, little notes all over the place, and arrows pointing forward and backword with annotations like "Move this part to after the bit on pickled cabbage."

Fig.2. Any program that can decipher my handwriting deserves respect.

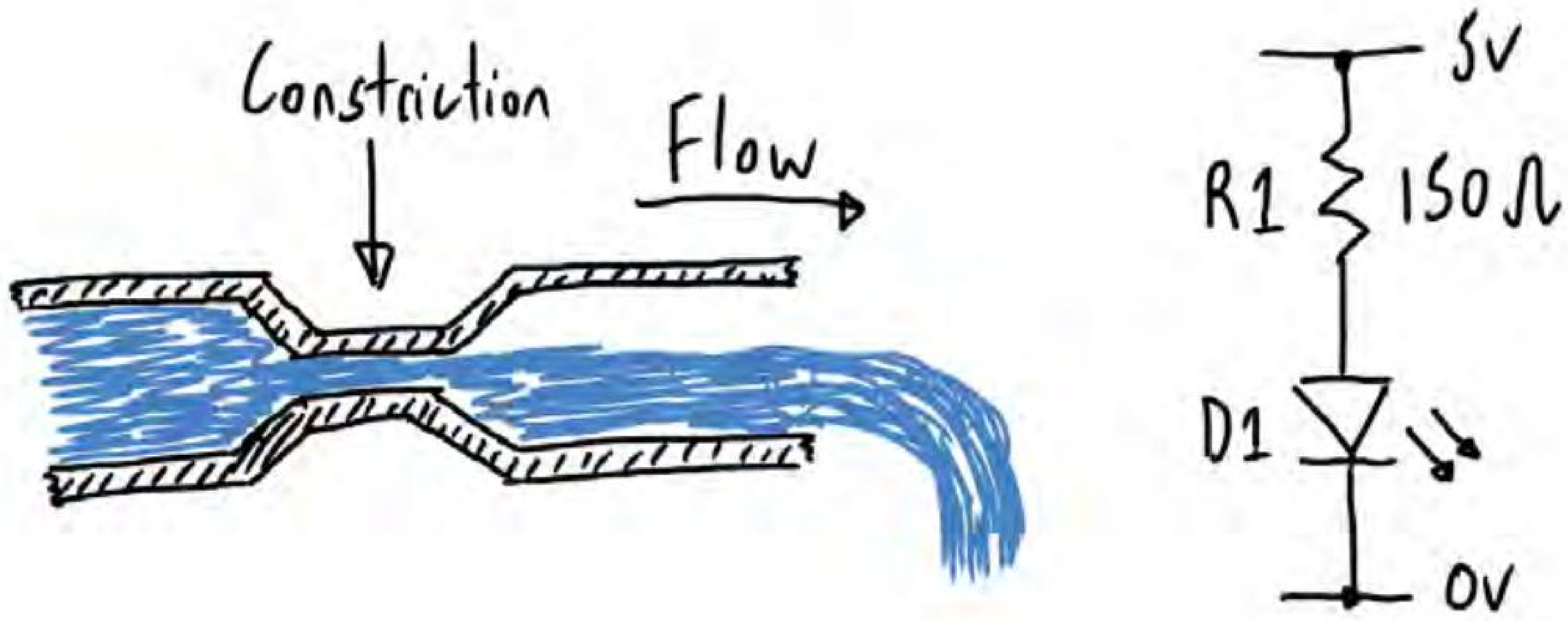


Fig.3. You can include equations, diagrams and sketches in your documents.

some of my own chicken-scratched notes on occasion. Over time, I became convinced that – at least in this regard – I was doomed to live a life of disappointment.

The triumph of the iPad

Returning to his aforementioned book, Asimov moved on to consider the triumph of the moon, which is that it does indeed orbit the Earth, and therefore has had a tremendous influence in helping life evolve the way it did. Without the moon orbiting the Earth, I would probably not be writing this column and you would probably not be reading it.

Everything started to change when I ran across a free app called MyScript Calculator in the Apple store. You can see a video of this little beauty in action on YouTube (**http://bit.ly/2bkgzWn**). As illustrated in Fig.1 (left), you can use your finger or a stylus to write an equation. When you pause, your handwritten input is converted into its machine-readable counterpart, including the result – as shown in Fig.1 (right).

The MyScript Calculator is incredibly easy and intuitive to use, and it's perfect for the myriad of rinky-dinky calculations I perform each day. This led me to the MyScript Nebo note-taking app (**http://bit.ly/2mQzEjU**). There was a bit of a stumbling block when I discovered that Nebo requires the use of an Apple Pencil, which is an active stylus that contains pressure and tilt sensors and communicates with the iPad via Bluetooth. There was an even bigger stumbling block when I discovered that the Apple Pencil costs $99.

Based on my delight with the calculator app, however, I decided to take the plunge, and I'm so glad I did. Using the Apple Pencil in conjunction with MyScript Nebo is as close to writing with a pen on paper as I've seen thus far. The interface is incredibly intuitive, and the quality and sophistication of the handwriting recognition simply blows me away.

You can easily add, modify, delete, and insert new text, swap paragraphs, and generally move things around. Whichever paragraph you are currently working on, a machine-readable version of the text appears in light gray above that paragraph. You can see the machine-readable version appear as you write. The handwriting recognition is context sensitive, and you can see it thinking and going back and updating existing words based on new words you've just added.

Double tapping on a paragraph will convert it to text, or you can tell the system to convert the entire document. Personally, I prefer to work with my handwritten notes, and only perform the conversion to text as part of emailing the document to my PC for a final edit.

In addition to text, you can also insert hand-written equations (using an embedded version of the calculator discussed above), intelligent diagrams, or hand drawn sketches like the one I just threw together in Fig.3.

As I mentioned at the beginning of this column, the combination of the Apple Pencil and the MyScript Nebo app has made a huge difference to the way I work. I cannot sing their praises enough (truth to tell, I can't sing at all). Now I must away to send this column to the editor at *EPE*. Until next time, have a good one!

Any comments or questions? – please feel free to send me an email at: **max@CliveMaxfield.com**

PCB SERVICE

CHECK US OUT ON THE WEB

Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

PROJECT TITLE	ORDER CODE	COST
DEC '15		
TDR Dongle For Oscilloscopes	04112141	£7.20
High-Energy Multi-Spark CDI For Performance Cars	05112141	£11.80
JAN '16		
Isolating High Voltage Probe For Oscilloscopes	04108141	£11.80
The Currawong – Part 3 – Remote Control Board	01111144	£6.95
FEB '16		
Spark Energy Meter – Main Board	05101151	£20.75
– Zener Diode Board	05101152	£7.50
– Calibrator Board	05101153	
APRIL '16		
Appliance Insulation Tester	04103151	£11.80
– Front Panel	04103152	£11.80
Low Frequency Distortion Analyser	04104151	£7.50
MAY '16		
2-Channel Balanced Input Attenuator for Audio Analysers and Digital Scopes		
– Main Board	04105151	£16.40
– Front Panel	04105152	£20.75
– Rear Panel	04105153	
Appliance Earth Leakage Tester		
– Main Board	04203151	£16.40
– Insulation Board	04203152	
– Front Panel	04203153	£16.40
4-Output Universal Voltage Regulator	18105151	£7.50
JUNE '16		
Infrasound Snooper	04104151	£7.50
Audio Signal Injector and Tracer	04106151	£9.64
– Shield Board	04106153	£7.48
– Demodulator Board	04106152	£5.36
Champion Preamp	01109121/22	£8.29
JULY '16		
Driveway Monitor – Detector Unit	15105151	£11.80
– Receiver Unit	15105152	£7.50
USB Charging Points	18107151	£5.00
AUG '16		
Low-cost Resistance Reference	04108151	£5.36
USB Power Monitor	04109121	£12.00
SEPT '16		
LED Party Strobe	16101141	£9.80
Speedo Corrector	05109131	£12.00
OCT '16		
Arduino-Based USB Electrocardiogram	07108151	£9.79
100W Switchmode/Linear Bench Supply – Part 2	18104141	£20.83
NOV '16		
Fingerprint Access Controller – Main Board	03109151	£12.88
– Switch Board	03109152	
DEC '16		
Universal Loudspeaker Protector	01110151	£12.88
9-Channel Infrared Remote Control	15108151	£16.42
Revised USB Charger	18107152	£5.36
JAN '17		
High-performance Stereo Valve Preamplifier	01101161	£17.75
High Visibility 6-Digit LED Clock	19110151	£16.42
FEB '17		
Solar MPPT Charger/Lighting Controller	16101161	£17.75
Turntable LED Strobe	04101161	£7.60
MARCH '17		
Speech Timer for Contests & Debates	19111151	£16.42
APRIL '17		
Microwave Leakage Detector	04103161	£8.00
Arduino Multifunctional 24-bit Measuring Shield	04116011	£17.75
– RF Head Board	04116012	
Battery Pack Cell Balancer	11111151	£9.00
MAY '17		
The Micromite LCD BackPack	07102122	£11.25
Precision 230V/115V 50/60Hz Turntable Driver	04104161	£19.35

*** See NOTE left regarding PCBs with eight digit codes ***

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

EPE SOFTWARE

Where available, software programs for *EPE* Projects can be downloaded free from the Library on our website, accessible via our home page at:
www.epemag.com

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards are available in PDF format free to subscribers – email **fay.kearn@wimborne.co.uk** stating which masters you would like.

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code **Project** **Quantity** **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**)

to: **Everyday Practical Electronics**

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:
http://www.epemag.com

CLASSIFIED

ADVERTISEMENTS

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).

All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: stewart.kearn@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it.

We have been the leading monthly magazine in this market for the last twenty-seven years.

BOWOOD ELECTRONICS LTD
Suppliers of Electronic Components
www.bowood-electronics.co.uk
Unit 10, Boythorpe Business Park, Dock Walk, Chesterfield,
Derbyshire S40 2QR. Sales: 01246 200 222
Send large letter stamp for Catalogue

ADVERTISE HERE FOR JUST £25 +VAT CALL STEWART KEARN ON 01202 880299
STEWART.KEARN@WIMBORNE.CO.UK

MISCELLANEOUS

PIC DEVELOPMENT KITS, DTMF kits and modules, CTCSS Encoder and Decoder/Display kits. Visit **www.cstech.co.uk**

VALVES AND ALLIED COMPONENTS IN STOCK. Phone for free list. Valves, books and magazines wanted. Geoff Davies (Radio), tel. 01788 574774.

WEARDALE ELECTRONICS
FOR ELECTRONIC COMPONENTS
& ELECTRICAL PARTS Etc.
SEND YOUR WANTS LIST TO
steve@weardale-electronics.co.uk
or BROWSE MY EBAY SHOP AT
http://stores.ebay.co.uk/weardaleelectronics
NO ORDER TOO SMALL – PERSONAL SERVICE

ELECTRONIC & HARDWARE COMPONENTS
EVERYTHING FOR THE HOME CONSTRUCTOR
www.partridgeelectronics.co.uk

CANTERBURY WINDINGS
UK manufacturer of toroidal transformers
(10VA to 3kVA)
All transformers made to order. No design fees.
No minimum order.
www.canterburywindings.co.uk
01227 450810

If you would like to advertise on the Classified page then please call Stewart Kearn on:

01202 880299

or email stewart.kearn@wimborne.co.uk

ADVERTISERS INDEX

BINARY DISTRIBUTION . . . . Cover (ii)
CRICKLEWOOD ELECTRONICS 46
ESR ELECTRONIC COMPONENTS 6
FUZE TECHNOLOGIES . . . . Cover (ii)
HAMMOND ELECTRONICS Ltd 23
iCSAT 47
JPG ELECTRONICS 72
LASER BUSINESS SYSTEMS 23
MICROCHIP . . . . Cover (iii), 10 & 51
PEAK ELECTRONIC DESIGN . . . . Cover (iv)
PICO TECHNOLOGY 47
POLABS D.O.O. 59
QUASAR ELECTRONICS 2/3
STEWART OF READING 23
TAG-CONNECT 47

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU
PHONE: 01202 880299
FAX: 01202 843233
EMAIL: stewart.kearn@wimborne.co.uk
WEB: www.epemag.com
For editorial address and phone numbers see page 7

Next Month

Content may be subject to change

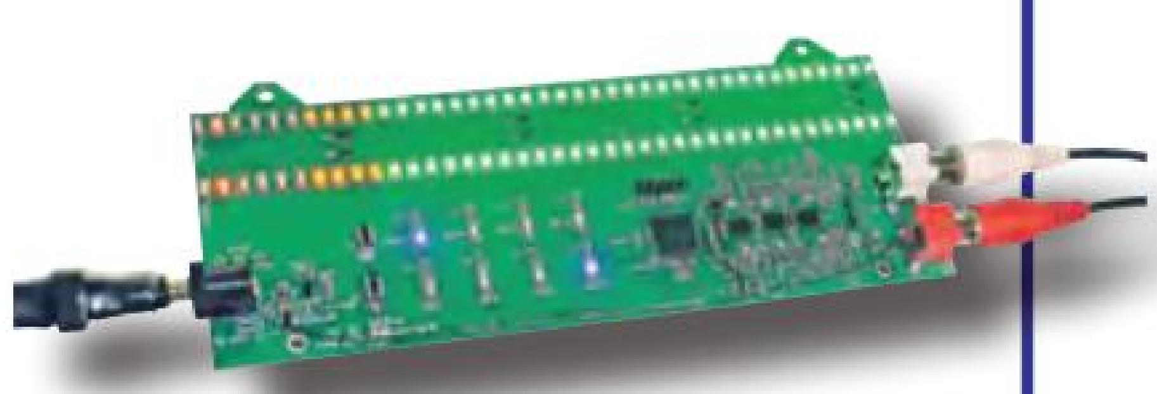
Ultrasonic Garage Parking Assistant

This handy *Garage Parking Assistant* will display the distance from the back wall of your garage or carport to your car's bumper bar, in large digits and with a colour coded background: green for go, yellow for slow down and red for stop. It makes positioning the car a breeze!

Hotel Safe Alarm
Unauthorised Opening
Door Open/ Alarm Pending
Enter Code
1
2

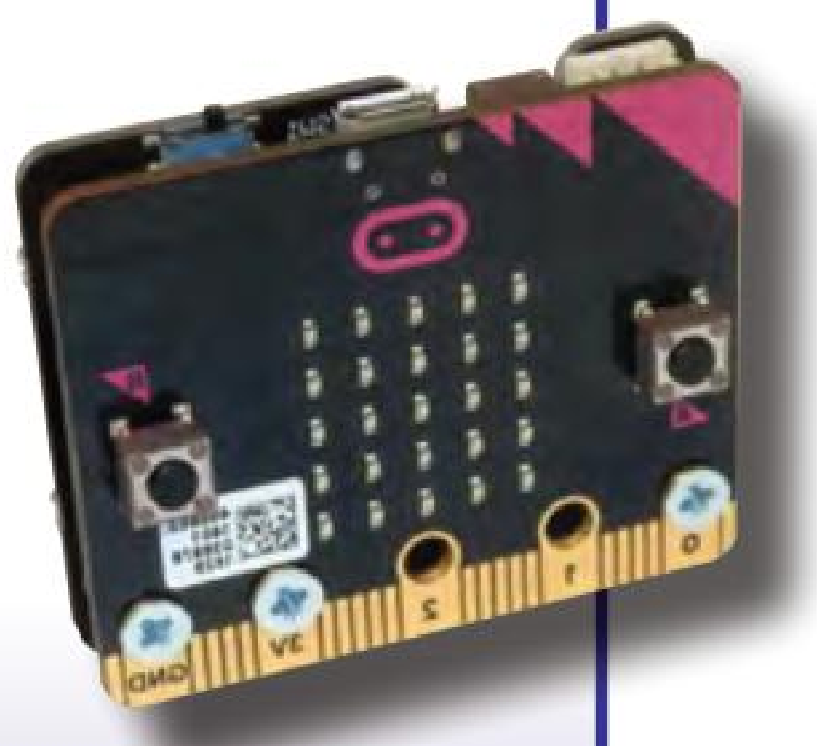
Hotel Safe Alarm

Are you a frequent tourist or business traveller? Then you will be familiar with the small safes provided in most hotel rooms. This *Hotel Safe Alarm* tells you if the safe has been opened in your absence and will also give the offender a very bad feeling that he or she has been detected. Their natural reaction will be to close the safe and abscond immediately.



100dB Stereo LED Audio Level/VU Meter – Part 1

Give your Hi-Fi system some WOW factor with this spectacular stereo VU meter. It uses 80 high-brightness SMD LEDs to give any stereo amplifier/mixer a highly colourful dual-bargraph display, which simultaneously shows the average audio signal level plus peak levels. And it can display signal ranges up to a whopping 100dB.



Teach-In 2017: Introducing the BBC micro:bit – Part 1

Following on from our popular *Teach-In* series on the Arduino and the Raspberry Pi, Mike Tooley has extended his investigation of low-cost microcontrollers to the recently introduced BBC micro:bit. In this first part, Mike introduces the board, explains the hardware and shows you how to get started with coding.

PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks, PIC n' Mix* and *Net Work.*

JUNE '17 ISSUE ON SALE 4 MAY 2017

WELCOME TO JPG ELECTRONICS
Selling Electronics in Chesterfield for 29 Years

Open Monday to Friday 9am to 5:30pm
And Saturday 9:30am to 5pm

- Aerials, Satellite Dishes & LCD Brackets
- Audio Adaptors, Connectors & Leads
- BT, Broadband, Network & USB Leads
- Computer Memory, Hard Drives & Parts
- DJ Equipment, Lighting & Supplies
- Extensive Electronic Components
  - ICs, Project Boxes, Relays & Resistors
- Raspberry Pi & Arduino Products
- Replacement Laptop Power Supplies
- Batteries, Fuses, Glue, Tools & Lots more...

T: 01246 211 202
E: sales@jpgelectronics.com
JPG Electronics, Shaw's Row,
Old Road, Chesterfield, S40 2RB
W: www.jpgelectronics.com

JPG Electronics

Retail & Trade Welcome • Free Parking • Google St View Tour: S40 2RB

Get the answer you've been looking for

PICs?
Can anyone help me?
Problem sourcing software?
General Electronics chat
I Can help!

Vist the EPE Chat Zone

www.epemag.com

Published on approximately the first Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £23.50 (6 months); £43.00 (12 months); £79.50 (2 years). EUROPE: airmail service, £28.00 (6 months); £52.00 (12 months); £99.00 (2 years). REST OF THE WORLD: airmail service, £37.00 (6 months); £70.00 (12 months); £135.00 (2 years). Payments payable to "Everyday Practical Electronics", Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

microchip DIRECT
PRODUCTS
APPLICATIONS
SERVICES
VOLUME PRICING
PROGRAMMING CENTER
SUPPORT
microchipDIRECT
Memory Programming
We Can Now Program Memory Devices
PRODUCT PRESS
CORPORATE PRESS
INVESTOR PRESS
UPGRADE TO A BUSINESS ACCOUNT
FREE PROGRAMMED SAMPLES
SMSC
NOW AVAILABLE
GET CONNECTED
BUY DIRECT
at
microchipDIRECT.com

microchipDIRECT offers access to the world's largest inventory of Microchip products and the most comprehensive online resource for pricing and support directly from Microchip Technology. We invite you as a valued Microchip customer to experience our service 24 hours a day, 7 days per week.

Visit www.microchipDIRECT.com and enjoy the confidence and convenience of buying from microchipDIRECT and take advantage of the following features:

- Direct stock from factory
- Direct customer service
- Secure ordering
- Volume pricing
- Credit lines
- Long-term orders and scheduling
- Programming and value add services
- Ability to adjust open orders
- Ship to your sites globally
- Online order status and notifications

microchip DIRECT
www.microchipdirect.com

MICROCHIP

www.microchipDIRECT.com

The Microchip name and logo, the Microchip logo are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2015 Microchip Technology Inc. All rights reserved. DS40001752B. MEC2010Eng04/15

PEAK®
electronic design ltd

2 Year Warranty as standard

UK designed and manufactured

Atlas DCA - Semiconductor Analyser model DCA55

Now with backlit display and AAA battery!

atlas DCA
model DCA55
PEAK
electronic design ltd
AAA Battery Edition
Base-Emitter V
VBE=1.039V
semiconductor component analyser
automatic lead identification
on - test
scroll - off
warning: avoid charge/voltages

103 x 70 x 20mm

- Connect any way round.
- Automatically identify component type.
- Automatically identify pinouts.
- Supports Transistors, MOSFETs, Diodes, LEDs and more.
- Measure transistor gain (h_{FE}).
- Measure V_{BE} (now 1mV resolution!)
- Measure leakage current.
- Measure MOSFET thresholds.
- Measure LED voltages.

Designed in the UK and made in the UK.

Just a few example screen shots:

```
PNP Germanium
Transistor       ↓
RED GREEN BLUE
Emit Coll Base ↓
Current gain
hFE=67           ↓
Test current
IC=2.50mA        ↓
Base-Emitter V
VBE=0.293V       ↓
Test current
IB=4.981mA       ↓
Leakage current
IC=0.027mA       ↓
```

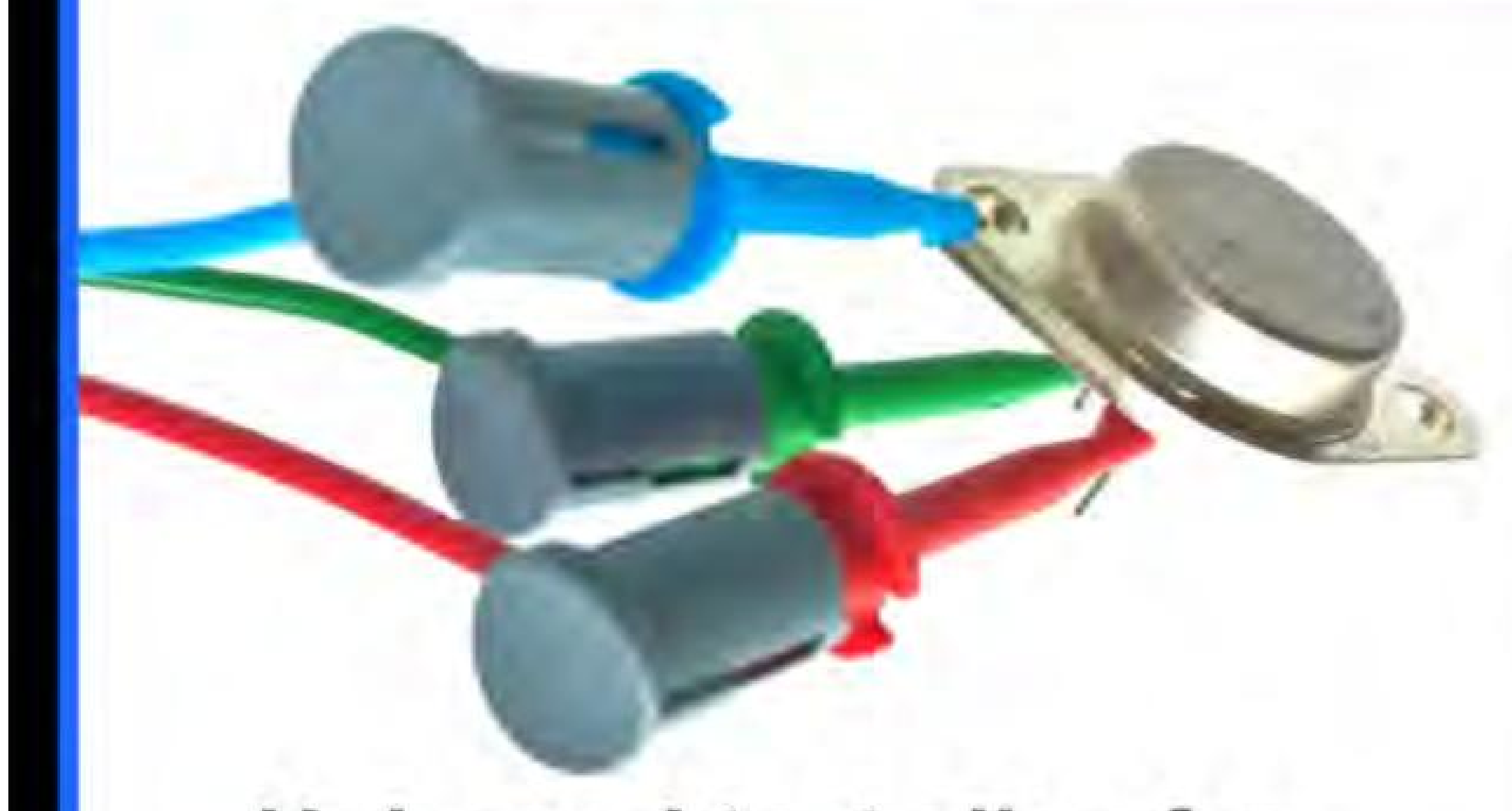
```
NPN Silicon
Transistor       ↓
RED GREEN BLUE
Base Emit Coll ↓
Current gain
hFE=117          ↓
Test current
IC=2.50mA        ↓
Base-Emitter V
VBE=0.711V       ↓
Test current
IB=4.583mA       ↓
Leakage current
IC=0.000mA       ↓
```

```
PNP Darlington
Transistor       ↓
RED GREEN BLUE
Emit Base Coll ↓
Diode protection
between C-E      ↓
Current gain
hFE=9124         ↓
Test current
IC=2.50mA        ↓
Base-Emitter V
VBE=1.321V       ↓
Test current
IB=3.720mA       ↓
Leakage current
IC=0.000mA       ↓
```

```
Enhancement mode
N-Ch MOSFET      ↓
RED GREEN BLUE
Gate Drn  Srce ↓
Gate Threshold
VGS=3.47V        ↓
Test current
ID=2.50mA        ↓

Diode or diode
junction(s)      ↓
RED GREEN BLUE
Anod Cath        ↓
Forward voltage
VF=0.694V        ↓
Test current
IF=4.663mA       ↓
```

```
Three terminal
bicolour LED     ↓
Pinout for D1
                 ↓
RED GREEN BLUE
     Anod Cath ↓
Forward voltage
D1 VF=1.983V     ↓
Test current
D1 IF=3.223mA    ↓
Pinout for D2
                 ↓
RED GREEN BLUE
Anod      Cath ↓
Forward voltage
D2 VF=1.927V     ↓
Test current
D2 IF=3.281V     ↓
```



Universal test clips for large and small components

Available direct from us and from our distributors:

RS maplin Rapid electronics Farnell

Peak Direct Price:

£48.00

(£40.00+VAT)

Peak's insured UK delivery £3.00 inc. VAT

It's only possible to show summary specifications here. Please ask if you'd like detailed data. Further information is also available on our website. Product price refunded if you're not happy.

E&OE

Tel. 01298 70012
www.peakelec.co.uk
sales@peakelec.co.uk

Atlas House, 2 Kiln Lane
Harpur Hill Business Park
Buxton, Derbyshire
SK17 9JL, UK

Follow us on twitter for tips, tricks and news.
@peakatlas